MINERAL RESOURCES OF BURMA

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THE MINERAL RESOURCES OF BURMA

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TO

MY WIFE

SHRIMATI VIDYA VATI CHHIBBER

in appreciation of her affectionate spirit of self-sacrifice and willingness to help me in my small endeavours.

PREFACE

IT was originally intended to publish the account of the geology and mineral resources of Burma in one volume, but later on it was found advisable to issue it in two parts. It really seems to have been the best course, as Burma, from the mineral resources point of view, is undoubtedly the most important province of the Indian Empire. The two books are complementary to one another, but the stratigraphy of important areas is sketched in the present volume, and petrographical detail is included where this has some bearing on the genesis of the mineral deposits. The present volume aims at giving an up-to-date account of almost all the important mineral deposits and mineral industries of the country, and some parts have been written entirely from personal observation. The chapter on jadeite may appear too lengthy, but that is perhaps justifiable. In spite of my best efforts to reduce the account to a reasonable size, I could not shut out the mental picture of the area I had before me. I spent about two years in the field alone in the Jade Mines area, and the same amount of time has been spent in the laboratory study of the rocks. It may be added that the chapter contains only the gleanings of my observations on the jadeite deposits. Similarly the chapter on amber offers but a summary of my work on these deposits, and also includes some recommendations with a view to improving the industry, and I feel myself lucky in removing several erroneous notions prevailing about these deposits.

In Chapters X and XI on tin and tungsten, the new areas which may be explored profitably have been briefly indicated. I feel almost confident that large areas which could be worked profitably for these metals lie unexplored in the somewhat remote jungles of the Tavoy and Mergui districts, especially

in the latter. The chapter on petroleum is contributed by Dr. L. Dudley Stamp, to whom I am grateful.

With the present boom in the price of the noble metal, I trust the chapter on gold will prove helpful to those who wish to exploit it, especially in the north. I think the salt industry can afford considerable scope to the at present unemployed youth of Burma, who with improved boiling methods, etc., as devised by the Government Salt Department, can earn their livelihood comfortably. I had the opportunity of discussing the subject with Mr. E. G. Robertson, Chief Collector of Salt Revenue, Burma, who also shares this belief. A considerable quantity of salt is imported annually into Burma from foreign countries. Would it not be worth while to keep that wealth within the country and the Empire ? Besides winning salt from the sea, the brine springs of the north, *e.g.* those of the Myitkyina district, also deserve attention.

It is interesting to note that the iron-ore deposits of the Northern Shan States are already finding use as a flux in the lead-silver smelters at Namtu ; but unfortunately the coal and lignite of Burma are too friable to be worked as such, though the time may arrive when they can either be briquetted or distilled. In Chapter XIII on miscellaneous minerals, several of minor importance have been briefly described. The establishment of a glass industry at Mergui perhaps deserves consideration from those interested.

In a mainly agricultural country the importance of soils can hardly be over-emphasised. Instances are not wanting, *e.g.* in the north of Burma, where the cultivation of paddy and sugarcane on haphazardly selected serpentine soil and on the Tertiaries, in spite of costly manuring experiments, was a failure ; while only a few miles away, the soil, indeed, proved ideal. I am grateful to Dr. S. P. Aiyar for discussing the chemistry, etc., of the soil-groups of Burma in Chapter XIV. Valuable suggestions in connection with this chapter were made by Professor G. W. Robinson of University College, Bangor, and by Dr. E. M. Crowther of Rothamsted Experimental Station.

Some of the information contained in the last chapter was collected by visits to the quarries, etc., of the different districts, and a preliminary communication on the subject was read before

the Geology Section of the Indian Science Congress, held at Calcutta in 1928.

Those whom I have the privilege of knowing personally are aware that the publication of the observations embodied in this work, and carried on almost continuously from the year 1924 to the end of 1931, was delayed by serious illness contracted in some of those disease-infested jungles of Burma. Later, two years were spent in London in rewriting the work and also in making further laboratory investigations; yet the author's labours will not have been in vain if the volume proves of any assistance to those who are interested in the development of the mineral resources of Burma.

Finally I have very great pleasure in expressing my indebtedness to Dr. A. K. Wells of King's College, London, who kindly undertook to see the book through the press on my departure from London. Acknowledgments have also to be made to those named in the companion-volume who so kindly read the proofs of parts of the book, more especially to Dr. J. Coggin Brown for his kindly interest and encouragement, both in the field and in the laboratory. As a student of Indian and Burmese geology, I should like to express my appreciation of the Bibliography of Indian geology and physical geography by T. H. D. La Touche.

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CHAPTER I

Geological and Geographical Distribution of Mineral Deposits.

BURMA is very rich in mineral resources, and deposits of petroleum, lead, silver and zinc, tin and tungsten ores, rubies, sapphires and spinels, jadeite and amber, gold, coal, etc., occur in different parts. It has been shown recently by J. Coggin Brown that the mineral deposits of Burma can be classified into seven geographical regions, each of which is associated with certain particular types or groups of rocks. Each group is marked by its own diastrophic events, when its mineralisation was brought about. Beginning from the east, the Author recognises the following six groups :

(1) Shan-Yunnan region. This group is largely composed of sedimentary rocks ranging in age from the Cambrian (?) to Cretaceous. Igneous rocks are not common. The mineral association is essentially a sulphidic one, comprising argentiferous galena, sphælerite, chalcopyrite, pyrite and stibnite. The occurrence of coal associated with the Jurassic rocks is also noteworthy.

(2) The Mogok-gneiss region is built of gneisses and igneous intrusive rocks with crystalline limestones. The crystalline limestone carries mainly the celebrated rubies, spinels and other precious stones, and also graphite.

(3) The Tenasserim region is composed of the quartzites and argillites of the Mergui Series, which have been invaded by granite. The important minerals characteristic of this region are cassiterite and wolfram, with smaller amounts of molybdenite, bismuthinite, chalcopyrite, pyrite, arsenopyrite, zinc-blende and stibnite.

(4) The Central Belt of Burma and the Arakan Coastal strip, including the islands of Ramri and Cheduba, are composed of

Tertiary rocks. They contain hydrocarbons, viz. petroleum, coal and amber.

(5) The Mingin group occupies a small but unique area, which is built of volcanic tuffs, andesitic breccia and conglomerate. Granodiorite with tourmaline pegmatites is intrusive into the volcanic rocks. Gold-telluride quartz veins, containing chalcopyrite, pyrite, galena, franklinite and altaite, are associated with the volcanic rocks.

(6) The Arakan-Naga region includes the serpentinised peridotites which carry chromite, native copper, chalcocite, chrysotile, steatite and magnesite. In the Myitkyina district jadeite is intrusive into these ultrabasic rocks.

The Plio-Pleistocene and Recent deposits occurring all over Burma contain lignitic coal deposits in the Northern Shan States and the Mergui district, also oil-shales in the Amherst and Mergui districts. With these may also be included the residual iron ores of the Shan States and the Kamaing subdivision, the manganese ores of Meiktila, the laterite of Lower Burma, the gem-gravels of the ruby mines, the gold and platinum placer deposits of the Irrawaddy, Chindwin and other rivers, the eluvial and alluvial wolfram and cassiterite deposits of Tenasserim.

The geographical groups, with their stratified and igneous rocks and the chief associated minerals, are shown in the table on the opposite page.[1]

Geologically, it will be noticed from the table that the rubies, sapphires, spinels, etc., are associated with the Archaean gneisses and crystalline limestone. Next follow the rhyolite and rhyolite tuffs of Bawdwin, which carry ores of lead, silver, zinc and copper. With the serpentinised peridotites of late Cretaceous to early Eocene age of the Arakan-Naga Hill ranges chromite, native copper, chalcocite, platinum, steatite, magnesite and jadeite are associated. As a complementary phase of this activity, the granites of the Eastern Hill ranges were erupted, and carry the ores of tin, tungsten, etc., extending from the Mergui district in the south to the Kyaukse district in the north. Later on, associated with the early Tertiary

[1] Modified from Dr. Coggin Brown, *Rec. Geol. Surv. Ind.*, vol. lvi, 1926, p. 66.

Geographical group.	Sedimentary rocks.	Igneous rocks.	Chief minerals.
(1) Shan-Yunnan	Cambrian (?) - Cretaceous	Rhyolite and rhyolite tuffs at the base of the Ordovician.	Argentiferous galena, zinc-blende, chalcopyrite, pyrite and stibnite.
(2) Mogok	Crystalline limestones.	Archaean gneisses, intrusive granite, syenites, nepheline rocks, etc.	Ruby, sapphire, spinel, graphite.
(3) Tenasserim with its continuation to the north.	Argillites, slates, quartzites.	Granites.	Wolfram, cassiterite, molybdenite, bismuthinite, native bismuth, chalcopyrite, arsenopyrite, pyrite, zinc-blende, stibnite.
(4) Mingin	—	Volcanic tuff, breccia, conglomerate with granodiorite and pegmatites.	Gold, chalcopyrite, pyrite, galena, franklinite, altaite.
(5) Central Belt	Eocene to Recent.	—	Petroleum, natural gas, coal, amber.
(6) Arakan-Naga	Triassic, Cretaceous and Eocene rocks in part.	Serpentinised peridotites, gabbro and microdiorites.	Chromite, native copper, chalcocite, platinum, gold, chrysotile, steatite, magnesite and jadeite.

volcanic rocks of the Wuntho region, gold, chalcopyrite, pyrite, galena, altaite, etc., were formed. In the Central Belt in Tertiary times, petroleum, natural gas, oil-shales, coal and amber were formed. In brief, during Archæan, Cambrian (?), late Cretaceous-early Eocene and early Tertiary times huge diastrophic movements occurred in Burma, accompanied by igneous activity, which brought about the mineralisation indicated above. Of course, petroleum, oil-shale, coal and amber are associated with the sedimentary rocks, and are undoubtedly of organic origin.

Tables showing the output of important minerals, together with their respective values for the quinquennium 1926–1930, are appended on the opposite page.

TABLE SHOWING OUTPUT OF MINERALS FOR PERIOD 1926-1930.

	1926.		1927.		1928.		1929.		1930	
	Quantity.	Value in Rupees.	Quantity.	Value in Rupees.	Quantity.	Value in Rupees.	Quantity.	Value in Rupees.	Quantity.	Value in Rupees.
Gemstones (Rubies, Sapphires and Spinels)	105,571 carats	4,66,772	39,590 carats	2,79,834	40,380 carats	1,77,512	43,650 carats	1,81,760	30,090 carats	1,31,155
Jadeite - - -	1,203·75 cwts.	2,34,456	2,227·03 cwts.	2,39,064	2,844·5 cwts.	2,85,984	3,450·95 cwts.	2,77,356	1,498·95 cwts.	3,66,487
Amber - - -	39·5 cwts.	21,420	70·5 cwts.	27,180	29·4 cwts.	12,020	19·585 cwts.	6,080	2·073 cwts.	730
Iron Ores - -	55,502 tons	58,122	56,204 tons	56,204	74,813 tons	74,813	41,001 tons	1,32,980	33,454 tons	1,04,354
Gold - - -	146·617 ozs.	12,618	59·667 ozs.	4,947	71·38 ozs.	5,807	36·112 ozs.	2,532	56·612 ozs.	4,450
Lead, Silver, Zinc and Copper Ores	362,880·3 tons.	1,13,74,006	454,733·5 tons	1,08,15,703	446,862 tons	1,19,56,862	468,023·1 tons	1,21,25,478	530,165·1 tons	1,41,10,267
Petroleum - -	250,040,471 gallons	9,20,90,865	245,904,044 gallons	5,22,15,324	262,187,263 gallons	4,91,19,173	253,400,524 gallons	5,36,34,977	256,554,026·83 gallons	4,23,62,916
Tin Concentrates -	2,772·10 tons	48,41,976	3220·48 tons	54,99,216	3,521·67 tons	51,58,726	3,668·65 tons	49,48,590	2,753·10 tons	32,87,929
Tungsten Ore - -	754·1 tons	3,80,213	165·788 tons	86,848	444·76 tons	86,848	1,059·60 tons	12,32,620	1,452·08 tons	10,75.583

CHAPTER II

GEMSTONES.

RUBIES.

BURMA has long been celebrated for its gemstones, especially the rubies, sapphires and spinels, and has been the principal source of supply of these gemstones to the world. Though the date of the first working of the mines is quite unknown, there is, however, no doubt that the mines have been worked for many hundreds of years. One of the sons of Kun-Lung, the founder of the Shan dynasty, is said to have governed a State, in the sixth century A.D., near to which there were ruby mines and for which he paid an annual tribute of two viss (one viss = 3·65 lb.) of rubies to the Central Government. In 1597 the mines passed into the hands of the Burmese Kings, who seem to have kept a very firm hold on them. They were let out on lease for a fixed annual sum, and, in addition to this payment, there was in existence a law by which all stones above a certain size were regarded as belonging to the King, who also reserved the right to confiscate any mine which, for some reason or another, showed good promise, and to work it himself. One of the earliest references to the Ruby Mines is that of Ludovico di Varthema, who visited Pegu in 1496.

Caesar Fredericke, who visited Pegu in 1569, describes the King of Pegu as " Lord of the Mines of Rubies, Safires, and Spinels " and states that the idols of the court were studded with " most rare Rubies and Safires," and refers to the brisk trade then being carried on in rubies. The English traveller, Ralph Fitch, was the first to make reference to the mines, though neither of these travellers was permitted to visit them. Père Giuseppe d'Amato was the first to give an authentic account. He describes the workings at Kyatpyen (22° 53′ 30″,

96° 28′) and the systems of mining then practised by the Burmese. This method may still be seen in operation in that neighbourhood. He says:

"The miners, who work at the spot, dig square wells, to the depth of 15 or 20 cubits, and to prevent the walls from falling in they prop them with perpendicular piles, four or three on each side of the square, according to the dimensions of the shaft, supported by cross pieces between the opposite piles.

"When the whole is secure, the miner descends and with his hands extracts the loose soil, digging in a horizontal direction. The gravelly ore is brought to the surface in a rattan basket raised by a cord, as water from a well. From this mess all the precious stones and any other minerals possessing value are picked out and washed in the brooks descending from the neighbouring hills. . . .

"The Chinese and Tartar merchants come yearly to *Kyatpyen* to purchase precious stones and other minerals. They generally barter for them carpets, coloured cloths, cloves, nutmegs and other drugs. The natives of the country also pay yearly visits to the royal city of Ava, to sell the rough stones. . . ."

With the annexation of Upper Burma, Mogok was occupied by the British in 1886. In October 1887 the Upper Burma Ruby Regulations (XII of 1887), framed to declare the law relating to rubies and other precious stones, came into force. By it the Local Government were empowered to notify the "stone tracts" and to make rules regarding the mining, cutting, possession, buying, selling and carrying of precious stones, and to grant licenses for these purposes. In November 1887 the Mogok stone tract was constituted. The history of the Burma Ruby Mines Company Ltd. is given in the sequel.

Rubies are known to occur in three important tracts in Upper Burma; but in all cases the original source of the gems is found to be a highly crystalline limestone. A fourth tract is reported to have been discovered in the Momeik State in 1913, but no definite information has been published yet. A stone tract is also known to occur within the State of Kengtung.

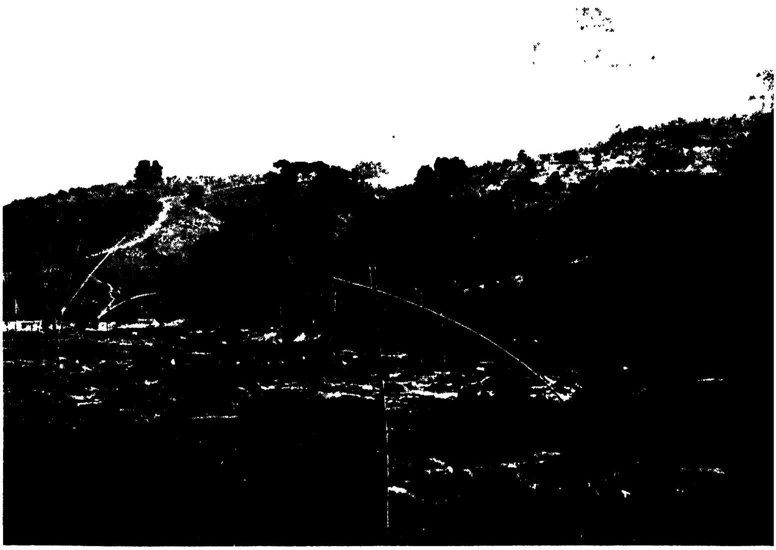
Ruby Mines, Mogok, Katha District.

The Ruby Mines tract in the neighbourhood of Mogok, Katha district, has been the most important source of rubies in Burma. The geology of the Ruby Mines area has been described in the author's *Geology of Burma*, Chap. XI, and it is sufficient to note here that the rocks belong to the Archaean, and comprise a complex series of highly metamorphosed paragneisses, granulites and crystalline limestones invaded by veins of aplite and pegmatite. The crystalline limestones carry phlogopite and graphite, and less commonly forsterite, diopside, tremolite, chondrodite, pyrites, apatite, spinels and rubies. In this district the ruby-bearing crystalline limestones form a series of narrow, parallel, lenticular bands, distributed *en echelon* along the southern flanks of the range of hills extending from the neighbourhood of Mogok (22° 55′, 96° 33′), where the most productive mines are situated, to Thabeitkyin on the Irrawaddy, a distance of about 40 miles in an east-west line. The other important area is Katha, a village seven miles by road, west of Mogok. At the 42nd mile south of Kabaing on this road other mines are situated at Sakangyi and yield rock-crystal and topaz. In the Kin valley, through which the road passes at the 37th mile, gems are also known to occur. Another gem-bearing area lies about seven miles north-west of Mogok, and represents the now deserted cantonment of Bernardmyo. The workings, therefore, are confined to the eastern half of the calcareous zone, between Shwenyaung (22° 55′, 96° 19′) and Mogok, where the character of the limestone bands indicates that they have been subjected to a more intense degree of metamorphism than farther west, where rubies appear to be absent. The rubies found here are generally of a carmine, cochineal or rose-red colour, with a play of violet, but the most valuable are of the colour of pigeon's blood.

Ruby Workings.

It has been found unprofitable to work the limestones for rubies owing to the relative scarcity of the gems. The native workings (Plate 1), however, as described by Barrington Brown and others, can be classified into the following three kinds:

PLATE I.



NATIVE GEM WORKINGS AT MOGOK.

Notice the lever arrangement used for hauling the débris.

(1) **Loodwin,** where fissures and hollows in the limestone, filled with detritus derived from its disintegration by weathering, are followed up and quarried. Small galleries or tunnels, just large enough for the men to crawl along, are made through the fissures and the softer or disintegrated parts of the rock, until a lode of decomposed limestone or a vein of gravel is struck. This earth or gravel is brought to the surface and carefully washed, and appears to be naturally concentrated, sometimes containing as much as 25 per cent. of rubies.

(2) **Hmyaudwin,** or cuttings driven into the rainwash covering the outcrop of the limestone on the hill slopes.

The Hmyau-working is a primitive system of hydraulic mining. An open cutting on the hillside is chosen, the lower end of which opens into a gully. Water channels are then constructed by digging trenches to conduct water from one of the mountain streams, often at a considerable distance along the hillside. to the cutting. The water is delivered at the top of the cutting, and flows away through a trench at the bottom, which forms a kind of sluice. The earth is excavated from the sides by hand and thrown into the sluice. The water, falling in a heavy shower on the earth, softens it and removes the clayey particles, while the sand and gravel are held by riffles placed across flumes at the lower end of the trench. This concentration is again puddled, the larger pebbles thrown away, and then the remainder is carefully searched for rubies and other precious stones.

(3) **Twinlons** are pits sunk in the alluvial deposits spread over the floor of the valleys, to reach the gem-bearing gravel, called *byon*, which generally lies at a depth of about fifteen to thirty feet. Bamboo levers on poles are then fixed round the mine, with rattan ropes and buckets attached, and these are used for hauling up the *byon*, or for baling the water from the pit (see Plate 1).

The fourth system of winning gem-stones is by washing the sand and gravel in the beds of streams. Sometimes a dam is built across a portion of the river, then, depending upon the depth, baskets of gravel are obtained either by hand or by diving.

The fifth method of working may be called quarry mining.

A limestone cliff is selected and the rock is detached by blasting, broken by hammers, and the enclosed rubies are chipped out. Owing to the crudeness of the methods the rubies extracted are somewhat damaged and the method therefore is not very popular.

History of the Burma Ruby Mines Company.

The first lease was granted to the Burma Ruby Mines Company in 1889, at an annual rental of Rs. 3,15,000. A second lease came into operation in 1897, and a third one for a period of 28 years in 1904. The Company was required to pay an annual rent of Rs. 2,00,000 *plus* 30 per cent. of the net profits made each year. It was in about 1907 that the market for gemstones became depressed. The slump continued in subsequent years and the value of production, of which the annual average was £84,000 during the period 1904–8, fell to £63,272 between 1909–13 and to £41,817 during 1914–18; between 1919 and 1923 it rose to £60,660.

The Company went into voluntary liquidation in 1925, and such stones as have been won since that date are due in part to its letting out certain gem-bearing areas on a modified tribute system. The regrettable demise of this famous concern, after its chequered career of 36 years, is best quoted from J. Coggin Brown's *Note on the Mineral Production of Burma during the year 1925.*

" The Sinkwa Mine was closed during the year. The best parts of the Mogok and Katha valleys are reported to be approaching exhaustion, and the residue of ruby-bearing ground in these areas is said to be insufficiently rich to pay for extensive working. These mines are now let out to tributors who clean up patches of ruby-earth left in crevices and detached spots. The loss on last year's working has finally exhausted the capital of the Company, which has since decided to go into voluntary liquidation."

In the opinion of J. Coggin Brown the present condition of gem-mining in Burma is due to the cumulative effect of numerous adverse causes; but the exhaustion of gem-bearing deposits is not one of them. The Mogok Stone Tract occupies

more than 600 square miles, and there are other valleys in the Stone Tract in which gems are known to occur, and which deserve fuller exploration than they have hitherto received, with the object of proving their value as hydraulicking propositions rather than as deposits to be opened up by costly and laborious hand methods.

Methods of Working of the Burma Ruby Mines Company.

The Company systematically works the alluvial deposits covering the floor of the Mogok valley and the *byon* is washed by most modern appliances, which comprise the washing plants working at Mogok and Katha. Each plant consists of a washing mill, where the material is dumped over screens, through trommels and into washing pans. At the end of the day the heavy concentrate from the pans is placed in trucks with covers, which are kept locked. The concentrates thus obtained are now transferred to the sorting shed, where they are introduced into a series of trommels. The material larger than five-eighths of an inch is sorted by hand at the sorting table. The material which passes the finest meshing of the trommels is allowed to run to the dump and is sold to the villagers of Mogok, who extract very small gems. The material of intermediate fineness passes from the trommels to the pulsators, where it is separated more thoroughly again into heavy and light fractions. The heavy fractions are carefully sorted by hand three times, whereby the gems of any value are almost entirely removed. The machinery is largely driven by electricity, which is generated from a waterfall at the outlet of the valley. Besides these washing plants there are several sluices at work, which supply concentrates for the sorting sheds.

In addition to the rubies the *byon* contains large quantities of spinel, usually of a brilliant red colour, and more rarely sapphires and crystals of apatite. Black tourmaline is also common, but is of little value as a gem.

Other Gemstones found in Ruby Mines Area.

(1) Apatite of a peculiar blue colour is found in Mogok.

(2) Chrysolite (peridot or olivine) of pale green colour is

said to occur in Bernardmyo and in Mogok. In the former locality it is apparently derived from the peridotitic rocks of the area.

(3) Chrysoberyl is rare, but is known to occur at and in the neighbourhood of Mogok.

(4) Moonstone is found east of Mogok.

(5) Garnet occurs very commonly in the Ruby Mines tract, but it appears to be sold in very small quantities by the local lapidaries.

(6) Iolite (cordierite or dichroite) or " water sapphire " is known to occur at Mogok, but is very scarce.

(7) Two varieties of lapiz lazuli occur at Mogok. The first variety has a deep indigo tint, the second is a white mass speckled with blue. The rock is composed of lazurite, haüyne, sodalite, and colourless minerals like white pyroxene, wollastonite, scapolite and calcite.

(8) Phenacite is of rare occurrence in Mogok.

(9) Epidote is also known to occur.

The output of rubies, sapphires and spinels during the years 1926–1930 is shown in Table on p. 5. In 1919 an exceptionally valuable ruby was found which was sold for three lakhs of rupees. The origin of the crystalline limestones in which the gems occur has been discussed in Chapter XI of *Geology of Burma.*

Sagyin Hills, Mandalay District.

About 16 miles north of Mandalay a group of hills composed of crystalline limestones, which are largely quarried for statuary marble, rises abruptly from the alluvial plain on the left bank of the Irrawaddy. Sir Henry Hayden was the first to report on the locality. Moisture, acting along the joint planes of the rock, has produced fissures and hollows, which have been filled with the insoluble clayey material furnished by the disintegration of crystalline limestone containing spinel and ruby. This clayey material is recovered from the fissures and washed for sapphires, spinels and rubies. The best yield is obtained from clay of a yellowish colour. According to Captain Strove the rubies from this locality are lighter coloured and therefore less

valuable than those of the Mogok neighbourhood. In recent years the workings do not appear to have been in a flourishing condition and no records of output are available.

Nanyaseik Stone Tract, Myitkyina District.

The author had the opportunity of examining the stone tract of Nanyaseik in the Myitkyina district, where rubies were first discovered in the neighbourhood of the Kammo *Hka* north of Nanyaseik (25° 37′ 11″, 96° 35′) in the early nineties. Subsequently, the local inhabitants commenced prospecting in other areas. A notification was issued by the Government on the 28th June, 1894, to regulate extraction. The license fee was fixed at Rs. 20 per worker, and in the year 1896 there was a big rush, as the revenue received in that year was Rs. 49,245. During the next four years, 1897 to 1900, however, the revenue fell away largely, the amounts credited being Rs. 3,090, Rs. 1,500, Rs. 1,250 and Rs. 1,750 respectively. The 1896 boom lasted only for a year, and in 1897 the license fee was temporarily reduced to Rs. 10. In 1901 the discovery of another gem-bearing area south-west of Nanyaseik led to a rise in the revenue to Rs. 4,225. However, the discovery of the new field and the large influx of workers in 1901 led the local offices to raise the rate again to Rs. 20, which was responsible for the considerable decrease in the revenue collected from the mines.

OLD MINING CENTRES.—The following are the old ruby mining centres:

Marrawmaw.—The old ruby mines lying between the Lahkraw *Hka* and the Marraw *Hka* are called by the Kachins *Marrawmaw*. The Lahkraw *Hka* is an important tributary of the Namya *chaung* and joins the latter about three-quarters of a mile south-south-west of the deserted village of Nanya (25° 37′ 20″, 96° 34′ 11″). There are numerous old shallow pits or open cuttings more than a few thousand in number along the stream banks. Their common depth and diameter is about three to four feet, but they have been partly filled with earth and overgrown with dense jungle. However, the maximum depth of a pit may be as much as about seven yards, though generally the depth varies from three to twelve feet.

The diameter of a big pit may be as much as ten feet. The general section seen in one of these ruby mines, in descending order, is as follows :

(3) Overburden : brownish, reddish or yellowish loam or alluvium at the top.
(2) Gem-bearing gravel or *byon*, one to four feet in thickness.
(1) Bed-rock or " phah " which is either granite or limestone. In the latter case the soil is very light and porous.

The author observed the following sections in two pits :

A. Overburden, loam, five feet six inches ; gem-bearing gravel or *byon*, one foot six inches.
Decomposed granite.
The water level was six feet four inches from the surface.

B. Overburden, loam, three feet ; gem-bearing gravel, two feet. Weathered lateritised granite.

The *byon* contains quartz, felspar, phlogopite, chlorite, calcite, spinel and ruby. The last two minerals seemed to be rather rare. It is interesting to note that the coarser the *byon* the bigger the rubies.

The author was informed that good rubies were comparatively more plentiful here than in other mining centres. When these mines are active Shan women wash for gold, as they do at present in the Jade Mines area, while their male relatives work for rubies and other gemstones. Numerous old workings are seen along the banks and the adjoining portions of a small stream locally called the Shayat *Hka*, issuing about half a mile north-east of the deserted village of Nawhkum (25° 39′ 2″, 96° 32′ 41″). A small outcrop of coarsely crystalline limestone in contact with granite is exposed in the stream. In another small stream, locally called the Kyan *Hka*, a tributary of the Kammo *Hka*, many old pits are to be seen in the beds, banks and vicinity of the stream. *Byon* here mostly consists of weathered granite detritus, derived from the contact of granite with limestone. In some places it is a bluish clay or loam on account of the decomposed felspar.

Mawthit.—On the west and south of the granite hill 804, marked on sheet 928/10, where it approaches the Kammo *Hka* the old ruby mines disappear, but reappear to the east of the above-mentioned hill. These old workings are called Mawthit.

It may be added that old workings are seen at intervals all along the left bank of the Kammo *Hka* and continue down to the Padau village (25° 37′ 54″, 96° 33′ 51″). The natives seem to have prospected in other places also, *e.g.* about four-fifths of a mile north of Padaw a few deep pits were seen away from the stream. Old workings (Mawgyi) are said to occur along the upper course of the Kammo *Hka* above the deserted village of Nawhkum. It must be noted that since these mining centres were deserted, now exactly 29 years ago, some confusion prevails about their nomenclature ; in particular, the Kachins and Shans have separate names for the same mining centres.

Another locality where the Kachins washed for corundum in the bed of a little hill-stream in the past is situated in the hills west of the Indaw *chaung*, about four miles north of Manwe. A. W. G. Bleeck mentions another locality, 13 miles north-west of Nanyaseik, where deserted ruby pits are also reported. Bleeck examined the gravel taken from the dry bed of the first locality, and its constituent minerals proved to be quartz, felspar, phlogopite, chlorite, garnet, spinel and corundum. The last two minerals are fairly abundant, more especially so the spinel, a handful of which can be collected in a few minutes. It occurs in octahedral crystals, up to half an inch in diameter. The colours of the spinels vary with the pellucidity, from an almost opaque dark green to a bright translucent red. The latter variety of colour, however, is rare. The corundum is not so abundant as the spinel, and the colour of this stone is dull pink. One of the larger pieces found measured three-fourths of an inch in diameter.

The mining methods practised at the time of working are described below. A small pit is worked by two miners, but generally three people work together. One man digs the earth with a very crude pick, another carries the earth away, and the third, when the *byon* is reached, starts washing. Water in the pit is baled out with long bamboo cups, sometimes two being tied together. This is a very tedious and slow process, and

pumping water with bamboo cylinders as used in the Jade Mines is recommended.

Washing is done on a flat bamboo basket about twenty inches in diameter. In the centre there is an area, ten inches square, the mesh of which is about one-tenth of an inch and is coarser than the rest. While panning, the bigger stones remain on the basket, the smaller ones pass through, and a constant eye is kept for small rubies in the material fallen below. Mayaws or water channels for a crude hydraulic sluicing of the overburden are also worked, especially during the rains.

Origin of the Rubies and Spinels.

In the Nanyaseik district limestone is well exposed in a number of important outcrops, some of which show intrusive contacts with granite. Where this is the case the limestone has been converted into a handsome marble, often coarsely crystalline, with calcites up to one and a half inches or more in length. Locally the marble is rich in accessory minerals, though normally it has been bleached to a pure white. Of these accessories the most abundant as seen in hand specimens is graphite, though this disappears in the process of section making. Next in order of importance are forsterite, largely converted into a pale-coloured serpentine, prismatic crystals of phlogopite, rounded grains and occasional euhedrons of garnet near hessonite in composition, small red or pink spinels, grains of chondrodite and pyrrhotite, apatite and very rare, deep red rubies, showing their distinctive basal parting.

The author's discovery of fossils in these rocks proves the marbles to be contact-metamorphosed Anthracolithic Limestone. The mineral-assemblage, forsterite-spinel-garnet, is characteristic of the contact-metamorphism (or dedolomitisation) of impure dolomitic limestones. Obviously aluminous sediment and silica must both have been present in the original rock. The occurrence of abundant corundum in the marbles of Mogok has been explained by the possible metamorphism of associated limestones and bauxites (the last being free from silica), rather than limestones and normal clay rocks.[1]

[1] Rastall, R. H., *Physico-Chemical Geology*, 1927 (Arnold), p. 145.

Both chondrodite and phlogopite are fluosilicates, and their presence in the marbles bears witness to the introduction of fluorine from the granitic magma, while the pyrrhotite may be either a product of pneumatolysis, or of the alteration of original pyrites.

Admittedly the same mineral-assemblage has elsewhere resulted from the *regional* metamorphism of impure (argillaceous) dolomitic limestones; and in this connection reference may be made to the fact that high-grade metamorphism of this type results in the disappearance of aluminous silicates such as hornblende, in favour of non-aluminous forsterite, while the released alumina appears as spinel, in the presence of magnesia,[1] or, one may assume, as corundum in its absence. In the Nanyaseik area, however, the field evidence is strongly in favour of the claim that the gems are products of contact-metamorphism. Their irregular distribution in pockets is probably due to original differences in the composition of the sedimentary rocks which were invaded by the granites.

It remains to be seen how far this explanation is applicable to the other occurrences of gem-bearing marbles—for example, at the Sagyin Hills and Mogok.[2] In the Mogok Stone Tract most of the rubies come from the crystalline limestones or marbles referred to on page 8, and are commonly enclosed in calcite. In these cases there can be little doubt that the rubies have originated by contact-metamorphism of dolomitic limestones as is claimed for the gems in the Nanyaseik area; but all the corundum gems have not originated in this way, as sapphires occur in pegmatite veins and in curious felspar rocks that are evidently desilicated acid intrusives. These consist of felspar, dominantly albite, with apatite as the only other constituent, and pass marginally into nepheline-bearing rocks, some of which resemble the corundum-syenites of South India.[3]

[1] Harker, A., *Metamorphism*, 1932 (Methuen), pp. 256, 257.

[2] La Touche, T. D., " Geology of the Northern Shan States," *Mem. Geol. Surv. Ind.*, vol. xxxix, 1913, p. 42.

[3] Brown, J. Coggin, *Mining Mag.*, vol. xlviii, 1933, pp. 329-340.

SAPPHIRE.

The blue and white varieties of sapphire are found commonly associated with the rubies in the crystalline limestones described above; but sapphires are not associated with the rubies in the limestones at Mogok. The proportion of blue corundum found in the gem gravels is usually much smaller than that of the red variety, though the stones are often of larger size. It is significant that at the well-known mine at Kathe near Kyaungdwin there are thick veins of the felspar rocks mentioned above, consisting of albite-rich microperthite. The sapphires here are obtained from detrital deposits, and it may well be that the gems have been shed into the latter from the igneous veins.

SPINEL.

Spinels are found in large quantities and in the same conditions at the localities described under "Ruby." In addition to the occurrences referred to above, Griesbach found large numbers of spinels in the sands of the Irrawaddy above Myitkyina, especially at the village of Watu (25° 30′, 97° 30′). They have also been reported to occur in quantity near the junction of the Pungin *Hka* and Mali *Hka* (25° 49′, 97° 32′), above the confluence.

ROCK-CRYSTAL AND TOPAZ.

Both rock-crystal and topaz occur at Sakangyi, near the 42nd mile-post on the Thabeitkyin-Mogok road in the pegmatite veins in the gneiss. In 1922-23 some extraordinary large crystals of transparent quartz were found, some of these measuring four feet long by one foot wide. The rock-crystal, which finds a ready market in China, is sought after by Chinese traders. Topaz also occurs in large, but very pale yellow to colourless, transparent crystals. The pale colour, however, renders it practically useless as a gem.

TOURMALINE.

Rubellite mines occur about a mile east of Maingnin (23° 14′, 96° 46′), surrounding the Palaung village of Sanka. The mines

are said to have been discovered by Chinese some 150 to 200 years ago, but were deserted until 1869, when they were re-opened by some of the Kachin chiefs. E. S. George has written a history of the working of these mines. The matrix of the tourmaline is described as a vein of granite which has become decomposed through kaolinisation of the felspar, and is covered by a considerable thickness of red surface soil. The white vein, known locally as *kyaw*, is reached by vertical shafts or *twinlones*, four feet square and varying in depth from 60 to 75 feet, while the maximum depth is about 100 feet. Each owner is allowed to extend his workings along the vein to a distance of about 30 feet from the centre of the shaft. The " veins " are fairly deep down, none having ever been reached at a lesser depth than about 54 feet, while the average depth is 60 or 75 feet. Working in the *twinlones* ceases in the rains. All the material dug out from inside the *twinlon* is hauled up to the surface in small buckets, all raised by enormously long pivoted bamboos worked with a counterpoise. The tourmaline is sorted out by hand, the granite fragments being piled in a well around the mouth of the shaft. Attempts to reach the vein by hydraulic sluicing have not proved quite successful owing to the lack of water except in the rainy season.

The tourmaline is very irregularly distributed and a successful venture is a matter of pure speculation. The mineral varies in colour from brown or black to a light transparent pink, the latter being of course the most valuable variety. The gems are sold by weight; the pink variety known as *Ahtet yay* fetches from Rs. 1,200 to Rs. 1,500 per viss (3·65 lb.), while the inferior variety is sold for about a third of that price. No returns of output are available since 1909, when it amounted to 5·1 lbs., valued at £36. It is stated to be impossible to give an average time as to how long it takes to collect a viss, as finding the gems is so uncertain.

Möng Lông, Northern Shan States.

The tourmaline-bearing gravels of Möng Lông form a river terrace situated higher up in the valley of the Nampai than the Ruby Gravel, and extend up to 200 ft. above the present level.

The workings are situated in the valley of the Nampai river, two or three miles to the north of the town of Möng Lông, in thick beds of gravel-like detritus washed down from the hill-slopes to the north of the valley. These hills are composed of gneiss, penetrated by broad veins of granite containing tourmaline as an accessory constituent. The gravels have been trenched in all directions in search of gems, a rude system of hydraulic sluicing being employed. Though black tourmaline is common, crystals of the red variety are said to be occasionally found. The output fluctuates considerably from year to year. In 1908, 32 stones valued at £289, and in 1909 seven stones valued at £26, were found, but since then no returns have been available.

Ruby Mines, Mogok, Katha District.

Rubellite is found in the southern part of the Ruby Mines under the same conditions as in Möng Lông. During the four years 1904–7 an average output of 101 lbs. of the mineral per year was recorded, but no returns have been received in the subsequent years.

Namôn, Karenni Hills.

At Namôn (19° 22′, 97° 35′), 13 miles to the north of Ywathit on the Salween river, crystals of a beautiful, dark green variety of tourmaline, varying from the size of a pea to that of a small bean, are found scattered through the surface soil, which is a brown sandy clay with pisolitic ferruginous concretions, and are mined on a small scale. The sandy material is taken out, sorted by hand and finally washed in the stream. The occurrence has been described by Middlemiss, who records that the matrix of the tourmaline is a white crystalline limestone, blocks of which are strewn over the hill-slopes where the pits are situated.

ZIRCON.

Both the flame-coloured zircon (hyacinth) and a blue zircon are found at Mogok and in the neighbourhood, but the colourless zircon, which simulates diamond in lustre, does not seem to occur.

BERYL.

According to Mason beryl occurs in the sands of the Irrawaddy, and this writer suggested that it might be found also in the streams descending from the hills to the east. Apparently no search has been made for these stones, but, however, aquamarine of a sea-green and bluish-green colour is found in granite-pegmatite at the Sakangyi mines, near the 42nd mile on the Thabeitkyin-Mogok road. It also occurs at Mogok.

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CHAPTER III

JADEITE.

THERE is little need to stress the interest and importance of jadeite. As a semi-precious stone of great beauty it has been known to man since very early times. It is greatly prized by the Chinese, with whom it is a sacred stone possessing certain magical properties, and by far the greater part of the total output of jadeite has eventually found its way to China ; but as the full appreciation of its wonderful colouring and its decorative value came to be appreciated, the demand has increased in Western countries also. To the geologist jadeite offers many problems, chief among them being the conditions of its formation, and several divergent views have been expressed by those who have studied the mineral and its associates. On these grounds the author feels justified in giving jadeite rather full treatment, particularly as he has had the opportunity of studying the occurrences in the field and of examining the rocks and minerals of the jadeite area in the laboratory.

The history of the jadeite trade from very early times up to 1893 has been summarized by Mr. Marry of the Chinese Consular Service and was reprinted in the Myitkyina District Gazeteer compiled by W. A. Hertz in 1912.

The first geologist to visit the jadeite mines was F. Noetling, whose preliminary report on the economic resources of the Amber and Jade Mines area in Upper Burma was published in 1892.[1] The same author published an article on the occurrences of jadeite in Upper Burma and illustrated the account with a small-scale map. Professor Max Bauer described the rocks and minerals collected by Noetling.[2]

[1] *Rec. Geol. Surv. India*, vol. xxv, 1892, pp. 130-135.

[2] *Rec. Geol. Surv. India*, vol. xxvii, 1895, pp. 91-105.

But he was under the serious disadvantage of not having studied the field relationships of these rocks. A. W. G. Bleeck visited the area in 1907 [1] and reference to his work will be made in the sequel. Recently Professor Lacroix also has published an account of the jadeite rocks of this region.[2] The author commenced the systematic survey of the jadeite-bearing region in 1928 and a brief resumé of his conclusions has been published in the General Reports of the Geological Survey of India for the years 1928, 1929 and 1931.[3] A complete list of references published on the jadeite of Burma is appended at the end of this chapter.

Area and Extent.—The area so far known at present in which the mineral jadeite is found in Burma, is situated between 25° 28′ and 25° 52′ N. lat. and 96° 7′ and 96° 24′ E. long. The co-ordinates given above include the main, well-known area which supplies almost the entire output of jadeite obtained in Burma. However, there are other places where jadeite is known to exist: one locality lies about ten miles east of Mohnyin (24° 46′ 50″, 96° 22′ 30″) and another one occurs on the bank of the Chindwin river. Jadeite also exists at about 200 miles north of Myitkyina, but the place is inaccessible and the quality of the jadeite is reported to be poor.

The region is a highly dissected upland, consisting of ranges of hills which form the Chindwin-Irrawaddy watershed. It is higher in the north than in the south, and Tawmaw (25° 41′ 13″, 96° 15′ 18″), which is situated on the plateau, is 2,755 feet above the sea. The highest point in the area is Mount Loimye, 5,124 feet above sea-level.

The Uru [4] *chaung*, the main stream of the area, runs along the foot of the plateau from north-east to south-west. Not infrequently this river has cut deep gorges, often flanked by cliffs or sheer precipices several hundred feet high. The current is rather strong and during periods of flood carries away whatever comes

[1] *Rec. Geol. Surv. India*, vol. xxxvi, 1908.

[2] *Bull. Soc. Franc. Miner.*, vol. liii, 1930, pp. 216-254.

[3] *Rec. Geol. Surv. Ind.*, vol. lxii, 1929, pp. 55-57 and pp. 108-114; *Ibid.* vol. lxiii, 1930, pp. 38-42 and pp. 97-102; *Ibid.* vol. lxvi, 1932, pp. 62-63 and pp. 85-88.

[4] Marked Uyu on the map.

in its way, so much so that more than half the important and flourishing village of Hpakan (25° 36′ 38″, 96° 18′ 40″), the centre of the jadeite trade, was washed away in 1927. The Uru is an

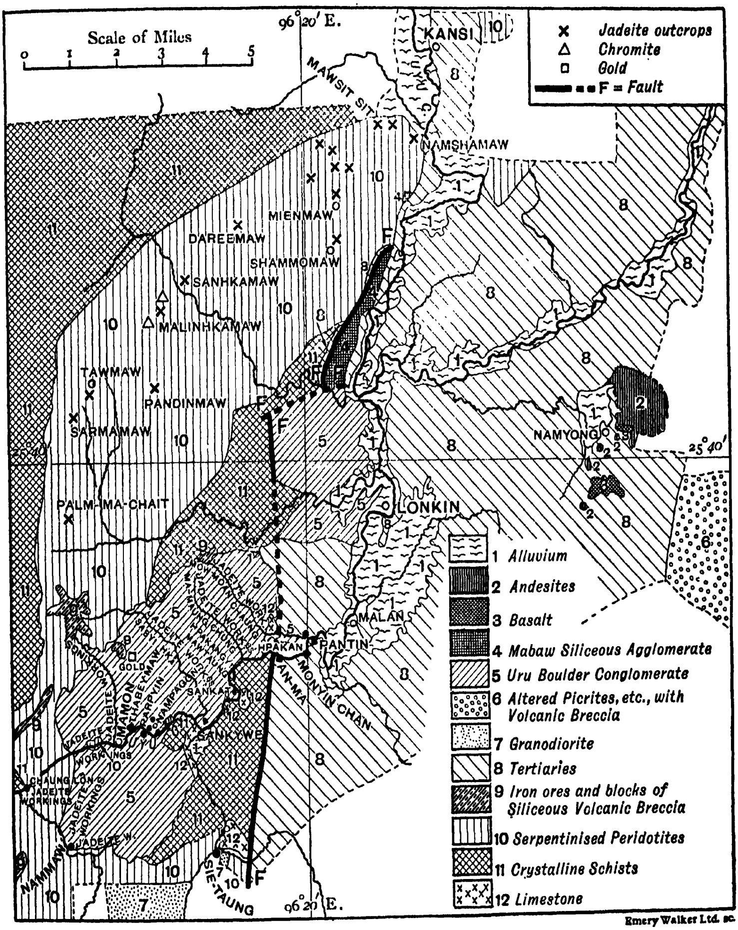

FIG. 1.—Sketch map showing the geology of the jadeite-bearing region in the neighbourhood of Kansi, Lonkin, Tawmaw, Hpakan, Mamon, etc.

important degrading stream, and its banks and small feeders are the scene of much mining activity for jadeite.

Tawmaw, where the true outcrop jadeite mines are situated, is about 68 miles by road from Mogaung railway station, which

lies on the Sagaing-Myitkyina branch of the Burma railways. From Mogaung to Nanyaseik (25° 37′ 6″, 96° 35′) there is an unmetalled motor road, but the portion between Kamaing (25° 31′ 38″, 96° 43′ 5″), the headquarters of the jadeite mines region, and Nanyaseik becomes very difficult after a few showers of rain. The tracks are flat for about another four miles from Nanyaseik, but beyond that there is only a well-graded, though locally very steep, mule-track passing over a range of hills.

GEOLOGY OF THE AREA.

There are serious difficulties in the way of detailed geological mapping: survey work is impeded by the almost impenetrable jungle, which in places is so thick that it is possible to see only a few feet ahead. Further, it is a particularly unhealthy region and the jungle is infested with insect pests.

Within the area much of the surface is occupied by Tertiary rocks (see Fig. 1), to the west of which lies a great intrusive complex consisting essentially of serpentinised peridotites, the outcrop being elongated north-east to south-west and being roughly oval in shape. This complex is surrounded by crystalline schists which include types derived from both sedimentary and igneous rocks. The former appear to represent the country-rock into which the plutonic complex was injected. The Uru Boulder Conglomerate of Pleistocene to Sub-Recent date occupies a considerable area north-eastwards from Nammaw, and is important on account of its jadeite workings. A brief account of each of the formations occurring in the Jade Mines area is included in this chapter. The succession is summarised in tabular form below:

XIII.	Alluvium - - - -	Recent.
XII.	Uru Boulder Conglomerate -	Pleistocene—Sub-Recent.
XI.	Volcanic Rocks - - -	Late Tertiary—Recent.
X.	Granodiorite - - -	Late Tertiary.
IX.	Gabbro - - - -	Late Tertiary.
VIII.	Namting Series - - -	Mio-Pliocene.
VII.	Hkuma Series - - -	Oligo-Miocene.
VI.	Highly altered picrites and volcanic breccias - -	Early Tertiary age.
V.	Jadeite-albite rocks - -	Early Tertiary age.

IV.	Granites	Late Cretaceous—early Eocene.
III.	Serpentinised peridotites	Late Cretaceous—early Eocene.
II.	Crystalline schists	Partly of unknown age and partly of early Tertiary age.
I.	Limestone	Palaeozoic, possibly Permo-Carboniferous.

The Plateau Limestone.

Small outcrops of limestone are common and their characters have been described in the author's *Geology of Burma*, 1934, p. 175. The limestone is generally crystalline, approaching marble, where it has been invaded by igneous intrusions. It is well jointed and occasionally it is highly brecciated.

The ordinary limestone, under the microscope, consists of calcite, forming irregular mosaics in places, set in a dusky, opaque material, which under high power resolves itself into extremely fine grained calcareous matter. A network of veins of calcite traverses the rock in all directions. The limestones yielded the remains of *Fenestella* and of foraminifera, including *Fusulina elongata*, *Textularia* and various forms of *Globigerinidae*. Minute circular and rod-like sections of *rhabdoliths* and *coccoliths* respectively are frequently observed under the microscope.

About one furlong west-south-west of the confluence of the Hwehka and Nammon *chaungs*, the limestone near its contact with serpentinised peridotites has undergone metasomatic replacement. Macroscopically it appears like a black chert, breaking with conchoidal fracture, and is seen to consist of an extremely fine mosaic of silica, the fossils also being replaced by this material. Perfect rhombohedral crystals of dolomite have undoubtedly resulted from the contact metamorphic effects of the serpentine intrusion.

Crystalline Schists.

Under the name of " Crystalline Schists " is here included the dual complex of basic igneous rocks, ranging from diorites and gabbros to pyroxenites and peridotites, and true schists. The latter are evidently older that the serpentinised peridotites and

other igneous rocks of the area and form the basement upon which the subsequent formations were deposited. The ortho- and the para-schists in places are so intermingled that it is impossible to separate them on the present one-inch maps. The ortho-schists encircle the peridotites and serpentines and are most probably the result of differentiation of the same magma. The prevailing type is epidiorite, especially striking when it contains white circular phenocrysts of saussuritised plagioclase: originally this rock must have been a gabbro. Other types which are quite common in the area include glaucophane-, hornblende-, chlorite-, kyanite-, quartz- and idocrase-schists. It may be noted that idocrase is a common constituent of the schists, especially of those collected near the limestones. Injections of pegmatite and aplite also occur in these rocks. The epidiorite proves to consist of rounded phenocrysts of saussurite embedded in a matrix of soda amphibole and actinolite. In places the amphiboles have been altered to chlorite. Inclusions of iron ores are present. The circular phenocrysts of felspar (saussurite) contain clusters of inclusions of amphiboles, zircon and iron ores. Some clear, secondary quartz is also present.

A rock obtained from the bed of the Sanhka *chaung*, about 2¾ miles north-east of Tawmaw (25° 41′ 13″, 96° 15′ 28″), contains, in addition to amphiboles and felspar (saussurite), colourless augite, garnet, zircon and zoisite. The augite is colourless and clear with an extinction angle of 48°, and shows simple twinning. The garnet is colourless and occurs either in dodecahedral or circular sections. Some secondary quartz is also present. Irregular aggregates of chromite are scattered all through the rock.

Graphite-schists.—Graphite-schists are fairly common in the area. It is not improbable that the epidiorites, described above, in places have been altered into these schists. They are greyish black in colour, sometimes with conspicuous reddish-brown pseudomorphs, which appear like garnets at first sight. With a pocket-lens graphite, quartz and some ferruginous material can be seen.

Thin sections consist of a schistose aggregate of quartz, graphite, with some mica and felspar. The phenocrysts are represented simply by circular, clear patches of quartz, which

in places are veined by limonite. It appears either that the felspar phenocrysts of the epidiorites, described above, have been replaced by limonite and quartz; or these pseudomorphs may be after garnet. Most of the quartz present in the rock appears to be secondary. It seems that along with dynamic stresses, hydrothermal waters containing silica, iron ores, etc., and *carbon* played their part in forming these schists. In places the minerals have been arranged in parallel folia but the latter have sometimes been bent and thrown into acute folds.

Quartz-schist.—Macroscopically, the quartz-schists are whitish, finely foliated schists which consist of quartz and felspar with reddish-brown streaks due to iron staining. Under the microscope a mosaic of the same two minerals is seen with a yellowish or yellowish-brown amorphous mineral, which in places assumes a reddish-brown colour on account of iron staining. Small lozenge-shaped, circular or needle-shaped crystals of sphene are also present.

Kyanite-schist.—Kyanite-schists were collected from one-third of a mile south-east of Saingmaw (25° 35′ 0″, 96° 17′ 30″), in the stream of the same name. They consist of glistening bright-green blades of kyanite set in a talcose matrix. In places sheaf-like aggregates are to be seen and the blades are often bent. Talc, it appears, has been formed partly by the alteration of kyanite, a fact confirmed by the microscope. The presence of kyanite indicates that the rock, presumably a sediment originally, has been subjected to high-grade dynamometamorphism.

Glaucophane-schist.—Glaucophane-schists are quite common in the area, and are greyish-blue rocks which, under the microscope, are seen to consist of glaucophane with some muscovite set in a granular mosaic of quartz. Generally the glaucophane occurs in prismatic sections, in places with conical terminations. The normal prismatic cleavage occurs along with transverse cracks. It shows the characteristic pleochroism: X, pale yellow to very light brown; Y, violet or light purple; Z, Prussian blue. The birefringence is weak. It appears that the mineral is an abnormal glaucophane,[1] since the sections containing the X-axis show rather wide extinction angles, the

[1] See Winchell, *Elements of Optical Mineralogy*, 1927, vol. ii, p. 209.

maximum being 22·5°, and the birefringence is stronger too in this case. In view of the presence of jadeite-bearing rocks in the neighbourhood, these glaucophane-schists are significant, as glaucophane contains the jadeite molecule.

Chlorite-schists.—The chlorite-schist from a little west-south-west of the Rest House of Mamon consists of greenish, ragged aggregates of chlorite formed as a result of the alteration of hornblende. The former shows its usual characteristics. Aggregates of colourless, granular augite are scattered throughout the rock. Associated with the chlorite are lenticles or irregular aggregates of saussurite in which numerous fine needles of amphibole occur as inclusions. A few irregular blebs of sphene and leucoxene are also present. The rock is evidently a normal 'green schist' formed at the expense of a basic igneous rock.

Vesuvianite-schist.—This rock proves very interesting under the microscope. It is seen to consist of prismatic, pyramidal and subangular sections of vesuvianite (idocrase) with imperfect prismatic cleavage and transverse cracks. Although most sections show normal characters, in places, however, apparently the same mineral shows ultra-blue polarisation colours and a maximum extinction angle of 21° measured on the prismatic cleavage. This probably represents the variety of vesuvianite recorded by Dana. The oblique extinction is most probably due to the great dynamic stress the rock has undergone. It is embedded in a schistose aggregate of quartz and felspar. Light green chlorite in thin flakes is also present.

A coarser textured specimen from near the junction of the schists and serpentines is similar, but contains more chlorite and felspar and is stained with limonite. Occasional sections of glaucophane are also present. Brownish haematite after magnetite also occurs.

Spotted actinolite-zoisite-schist with pegmatitic injections. A specimen, collected from the Nangma *hka* just a little south of " h " of *hka* (92 C/6), consists of granular aggregates of actinolite, zoisite, epidote, and vesuvianite with a little augite, quartz and felspar. The felspar occurs in circular sections containing numerous inclusions of acicular actinolite. Of these minerals, zoisite is the most interesting and forms a fair proportion of the rock.

The schist is injected by fine pegmatites consisting of quartz and muscovite.

Another similar rock from the Sanhka *hka*, less than half a mile west of " 897," contains muscovite in addition to the minerals described above.

Mica-pegmatite.—Mica-pegmatites were observed in the Sanhka *chaung*, about 2¼ miles S.W. of Kansi (25° 47′ 1″, 96° 22′ 48″) . They consist of a granitoid aggregate of quartz, felspar and muscovite, the last mineral occurring in elongated blades. It is also present as inclusions in felspar, and in places the felspar and muscovite form a micrographic intergrowth and enclose sections of quartz. Thin aplitic veins consisting of a fine granular mosaic of quartz and felspar with a little mica are seen traversing the rock. Prismatic sections and irregular blebs of colourless vesuvianite also occur.

Hornblende-peridotite.—Specimens of a very interesting rock were obtained from the first stream, *en route* to Sietaung, about half a mile north-east of " 1316 " hill marked on the map (sheet 92 C/6). Macroscopically the rock is a beautiful aggregate of glistening black crystals of hornblende and pale green olivine. Small crystals of a reddish-brown mineral are also visible. A thin section consists almost entirely of bluish-green hornblende (smaragdite) with some clear olivine, diopside, and greenish augite. Titanite or rutile also occurs both in rounded and prismatic sections. The rock is actually a hornblende-peridotite near to hornblendite of Dana. A similar rock was discovered as an ejected block from the Twindaung crater in the Lower Chindwin region.[1]

Granite-gneiss.—A coarse porphyritic granite-gneiss, which is interbedded with the crystalline schists, is seen in the Sage *hka*, a stream which joins the Hkara *hka* about one furlong from the latter's confluence with the Tanai *hka* on one-inch Survey of India Sheet 92 C/13. The gneiss shows a texture varying from that of a fine grained schistose rock to that of a coarse granite-gneiss. In the Tanai *hka*, near its confluence with the Hkara *hka*, it assumes the aspect of a micaceous schist, being very finely bedded and dipping north-east at high angles. It is also highly jointed and cleaved into small pieces, moreover,

[1] *Trans. Min. Geol. Inst. Ind.*, vol. xxi, 1927, p. 216.

the dip is vertical, the rock is very crumpled and shows evidence of minor strike-faulting.

Serpentinised Peridotites.

An extensive complex of peridotites, which in places have been partially or wholly altered to serpentine, extends southwards from the Sanhka *hka* (on the one-inch sheet 92 C/5) and a tributary of the Namsai *hka* to the latitude of Haungpa (25° 30′ 48″, 90° 6′ 15″). A. W. G. Bleeck depicted it as two separate outcrops ; but it is really one continuous mass as seen in the Uru *chaung* below Mamon (25° 35′ 10″, 96° 15′ 57″). Another outcrop on the one-inch sheet forms the hills " 1448 " and " 1660," while another mass, slightly east-north-east of Kansi, forms hill " 2162 " (one-inch sheet 92 C/5). It is overlain by the Tertiaries to a height of about 1,200 feet and the remaining part of the hill is composed of serpentine which is highly brecciated in places. South and east of Hwehka, serpentine again outcrops, and must be connected underground with the main mass, but crystalline schists intervene for a little over one and a half miles west of Kadonyat (25° 3′ 20,″ 96° 15′ 46″).

A thick mantle of red soil covers the rocks, the ferruginous content of which has been concentrated in places to form iron ores. The peridotites include several different types, the most important being dunite-, mica-, hornblende- and diallage-peridotites, in addition to diallage-perknite (pyroxenite) and amphibolite. The serpentised dunite from Tawmaw with a density of 2·795–2·802 on analysis by M. Raoult yielded the following results :

SiO_2	34·34
Al_2O_3	0·37
Fe_2O_3	3·60
FeO	7·04
MnO	0·15
MgO	42·58
CaO	0·54
Na_2O	0·41
K_2O	0·17
TiO_2	—
P_2O_5	tr.
H_2O+	10·12
H_2O-	0·31
Cr_2O_3	0·49
	100·12

Granites.

In the Myitkyina district[1] of the Jade Mines area granite occupies a wide expanse of country, forming thickly forested hills up to 1,500 ft. in height, and scattered knolls. The wide extent of the granite suggests that it has the form of a batholith, and it may be regarded as complementary to the ultrabasic complex described above, and of approximately the same date. In the main the rock is a medium-grained pink or grey granite, a type containing biotite being dominant. In addition to this, however, two-mica granite, hornblende-granite and micro-granite, as well as more basic types, including monzonites, are well represented, while dioritic xenoliths in the acid rocks may well be interpreted as digested fragments of even more basic, early types.

In texture the granite varies from the normal xenomorphic granular to graphic and micrographic, and there is frequently a slight foliation to be seen, impressed on the rock during the consolidation of the magma. Magmatic residua are represented by pegmatites and aplites, while the final product of consolidation was quartz which frequently veins the granite.

These rocks are of special significance in connection with the problem of the origin of the unique jadeite-albite rocks, considered in detail below.

Altered Picrites and Volcanic Breccias.

Locally volcanic rocks, associated with highly altered picrites, occur, and perhaps represent the extrusive phase of the same igneous cycle which gave rise to the ultrabasic and acid complexes described above. As they are of no significance in connection with the genesis and exploitation of the jadeite-bearing rocks, it is not necessary to describe them fully, and only notes on some of the more interesting occurrences are included in this account.

The picrites are represented often by rocks exceedingly rich in epidote, so much so that the term " epidosite " seems the most appropriate name to apply to them. In addition to the abundant epidote, haematite and limonite also occur and are

[1] *Rec. Geol. Surv. Ind.*, vol. xliv, 1930, p. 98.

generally seen filling up the central portions of the felspars. Serpentine with some chlorite also occurs in ragged or irregular patches.

These epidosites bear a striking resemblance to similar rocks from Punta Parate, Ajaccio, Corsica, and also to those from the Lizard, Cornwall, England. Originally they must have been very basic rocks, probably picrites, but the ferromagnesian mineral, mostly pyroxene, which is still seen in residual patches in some slides, and felspar have been changed by metamorphism to epidote.

Altered andesite-tuff.—A light-grey rock which reveals its clastic character under close observation is commonly associated with the epidosites described above. Under the microscope it is seen to be composed of fragments of volcanic, particularly andesitic, rocks. The latter contain large prismatic and octagonal phenocrysts of augite and prismatic felspars set in a fine grained groundmass containing magnetite crystals. The felspar in some cases is rendered opaque, while in others it is altered to a mosaic of secondary felspar and sericite. Some rock-fragments in the tuff consist of aggregates of fine lath-shaped felspars, with some augite, while others are altered almost entirely to greenish serpentine with grains of magnetite. Some are dark and almost opaque.

In addition to several different kinds of andesite (of which augite-andesite is the chief), fragments of dolerite, serpentine, and palagonite with small globulites also occur. Since the fragments of andesite predominate, the rock is an andesite-tuff. Similar rock occurs just beyond the eighteenth mile on the Kamaing-Tawmaw road and just east of the stream.

Serpentine tuffs.—Serpentine-tuff, derived from basic rocks, was collected from the first S.W. bend before the nineteenth mile on the Kamaing-Tawmaw road.

In some of these tuffs epidote is present in abundance and angular fragments of the epidosites described above have also taken part in their constitution.

Quartz-hornblende-dolerite.—A small outcrop of intrusive dolerite was observed about two-fifths of a mile N.W. of the twenty-first mile on the Tawmaw–Kamaing road. The rock is dark grey in colour, of medium texture and weathers by

exfoliation. The specific gravity is 2·70. The constituents seen under the microscope are felspar, primary hornblende, uralite, quartz, apatite and magnetite with a little limonite. The felspar forms columnar and tabular crystals with inclusions of hornblende. In places it forms an almost homogeneous base in which long thin laths of labradorite are crowded together almost to the exclusion of other minerals. Green hornblende occurs both in idiomorphic and hypidiomorphic sections, but some portion of it is uralitised, while in places residual augite is seen associated with it. Quartz is interstitial, and apatite, in the form of needles, and magnetite occur as accessories. The texture is subophitic. The rock appears to be undoubtedly a basaltic dolerite ; its porphyritic character is noticeable.

Siliceous injections.—These rocks have been injected with siliceous veins, *e.g.* near the stream, before the twentieth mile on the Kamaing–Tawmaw road. The rock is compact, slightly greenish in colour and under the microscope it is seen to consist of an extremely fine mosaic of quartz, felspar, sericite with a considerable proportion of opaque material which appears whitish by reflected light, and may be altered felspar.

The Tertiary Rocks.

The author has classified the Tertiaries of this region as follows:

(2) Namting Series - - Mio-Pliocene.
(1) Hkuma Series - - Oligo-Miocene.

The Hkuma Series.

Good sections of the Hkuma Series are exposed along the Shadu, Tagam, Hkuma and Hkada streams, of sheet 92 C/13, but since they were first met in the Hkuma *hka* and also form the high hill, 4,982 ft. above sea-level, known as Hkuma Bum, the author has designated them the Hkuma Series. In the Shadu *hka*, almost from its source to its confluence with the Sumpra *hka* they show a northerly dip which, however, fluctuates between north-west and north-east, at an average of 45°. Sandstones with occasional interbedded layers of shale or argillaceous sandstone are predominant. In places they are finely laminated, while in others they are coarse and pebbly.

The most striking feature is their extremely well-bedded character. They are greyish, greenish, whitish, pale-yellow or reddish in colour, sometimes with black carbonaceous streaks. In the Shadu *hka* alone, about 10,000 feet of these sandstones are exposed. In the Tagam *hka* sandstones are interbedded in places with black carbonaceous shales, which are sometimes very friable. Both sandstones and shales contain well-preserved fossil leaves ; those from the neighbourhood of Hwehka include *Tetranthera hwekonsis*. The shales are generally of a greyish colour and thin sections show dark-brown carbonaceous matter together with a considerable amount of calcite, some quartz and a little mica. A number of foraminifera belonging to the family *Globigerinidae* were observed in the shales from Hwehka (25° 29′ 3″, 96° 16′ 43″), and this tends to prove that a small inlet of the deep sea existed in the neighbourhood. This must have undergone very rapid changes as is shown by the interbedding of conglomerate, containing boulders of jadeite, various types of serpentine, peridotite, amphibolite, and hornblende-, graphite-, mica- and quartz-schists, proving that these rocks were exposed when the Tertiary sediments were being deposited. Bands of finely jointed, black, carbonaceous limestone also occur. The occurrence of coal and lignite is noteworthy.

On sheet 92 C/13 their junction with the crystalline schists and serpentines is faulted, as is shown in the Hkuma and the Hshamshing *hkas*. Similar rocks are also met with in the upper course of the Namjan *hka*, on sheet 92 C/5, and the upper portion of 92 C/6. They are the freshwater equivalents of the Pegu Series met with farther south, but it is possible that their base touches the Upper Eocene, as the heavy-mineral assemblages of some of the specimens correspond with those of the Barail Series (Eocene-Oligocene), of Assam.

Namting Series.

Since the Upper Tertiary rocks containing fossil wood were first met with near Namting (25° 38′, 96° 27′), they have been called the Namting Series.[1] The type area lies between Namting and Lonkin (25° 39′, 96° 22′) which are eight miles apart. Their thickness must be considerable, since in places the strata

[1] *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, p. 88.

are vertical. They consist of sandstones, shales and conglomerates. The sandstones are of various colours, coarse to medium in grain size and sometimes pebbly. They contain many minerals, but quartz and felspar (both orthoclose and plagioclase), are predominant. Grains of epidote, glauconite, chlorite and serpentine are quite common; while muscovite, biotite, haematite, chromite and calcite also occur. Small grains of graphite and of graphite-schist are also present, while grains of jadeite prove that the intrusion of the jadeite-bearing rocks must have preceded the deposition of these rocks. Some of the sandstones are calcareous, but the majority are argillaceous. Small trunks of silicified dicotyledonous fossil wood were seen about a mile west of Namting, and small stumps of fossil trees, comprising both palms and dicotyledons, were found a little south-east of Namyong (25° 40′, 96° 26′). The inner portion of some is carbonised, but the outer is silicified.

Similar rocks are exposed in the Tarong *hka* near Tarongyang (25° 40′, 96° 45′), and the Tertiary rocks forming the low hills near Nanyaseik (25° 37′, 96° 35′) also belong to this series which is the equivalent of the Irrawaddy Series described in Chapter XXIV of the companion volume.[1] Specimens collected from them yielded heavy minerals, which, with a very few exceptions, agree closely with those from the Tipam Series of Assam.[2]

The late-Tertiary Plutonic Rocks.

Gabbro.—Gabbro first appears about one and three-quarter miles west-south-west of △ 5124; in the Namjan *hka* which has cut a gorge with steep cliffs as far as its junction with the Loimye *hka*. From the latter point the rock ascends and is exposed at about 750 feet above the level of the stream and is overlain by the volcanic deposits of Mount Loimye. A little over half a mile north of △ 5124 it again makes its appearance and forms the " 4842," Bum-i-Bum, and " 4858 " hills, whence it extends northwards as far as the headwaters of the Namjan *hka* where the latter bifurcates into the Dab-Bum and the Chinkichu *hkas*. The gabbro is intrusive into the Tertiaries; in places *lit-par-lit* injection is seen, and xenoliths of the latter occur in the former. It is very finely banded locally, and towards

[1] *The Geology of Burma*, Macmillan, 1934, pp. 250-258.
[2] P. Evans, in *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, p. 88.

its western boundary easterly dips ranging from 30°–50° are observed. Similar banding has been recorded in the case of the Tertiary gabbro of Skye.[1] East of the Namjan *hka*, north of its confluence with the Loimye *hka* for about 2 miles the gabbro comes into contact with greenish black basaltic tuff and, as a result of the intrusion, the latter has been baked, hardened, bleached and metamorphosed. Very probably this marks the position of one of the older vents which served as passages for the uprise of the basic eruptive rocks.

The form of intrusion near the eastern margin appears to be a concordant, inclined, composite sill or sheet.

The rock is generally of a greyish colour mottled with ferro-magnesian minerals and shows considerable variation in texture. In places it is so fine-grained and granulitic that, without the aid of a microscope, it is difficult to distinguish it externally from basalt. However, coarse, massive gabbros are most common. The different modifications are described below :

Massive, Coarse Gabbro.—In the massive, coarse-grained gabbro the individual crystals of augite measure over 5 mm. in places. The specific gravity is 2·858. The thin section consists of a very coarse-grained aggregate of altered felspar and augite. The augite has altered, first to serpentine, which has further altered to a brownish opaque material with lacunae of chalcedony. Quartz and iron ores are also present.

Microgabbro (Porphyritic).—The rocks from the periphery of the sheet, represented by specimens collected from the left bank, just before the Namjan *hka* bifurcates into the Dab-Bum and the Chinkichu *hkas*, is finer-grained in texture. Under the microscope it is seen to consist of a fine-grained aggregate of felspar, augite and hornblende with a fairly large quantity of iron ores (magnetite and ilmenite) which make the rock look more basic than the one described above. Felspar is seen in places to occur in comparatively large phenocrysts. The specific gravity is 2·86.

Quartz-augite-enstatite gabbro.—Another variety is coarser in grain size, is greyish in colour, mottled black with pyroxenes. The specific gravity is 2·89.

Thin sections of this type consist of a xenomorphic-granular

[1] *Q.J.G.S.* vol. 50, 1894, p. 645.

aggregate of labradorite felspar and pyroxene, the texture being sometimes ophitic. The pyroxenes include both diopside and enstatite, but the former is predominant and in places a micrographic intergrowth of the two is seen. The enstatite appears to be ferriferous since in places it is slightly pleochroic. The pyroxenes have altered to both fibrous hornblende and serpentine. Some interstitial quartz is also present. Magnetite occurs in large hypidiomorphic patches. A little green mica, partly chloritised, is also present.

Micrographic Gabbro.—The rock collected from the Namjan *hka*, about a quarter of a mile south-east of its confluence with the Loimye *hka*, is greenish white in colour, and is composed of elongated crystals of felspar and augite, some of which measure over 10 mm. in length, though their breadth is not much over 2–3 mm.

In thin section this type is seen to consist of much elongated prismatic sections of felspar and diallagic augite, the former interpenetrating at various angles, forming sometimes star-and-cross-shaped aggregates. The interest lies in the groundmass which consists of a fine micrographic intergrowth of quartz and felspar; but not infrequently two felspars appear to be intergrown, though it is very difficult to ascertain their specific characters. Iron ores as usual are present. The rock seems to be an acidic alkaline gabbro and its chemical analysis [1] is tabulated below:

	Graphic gabbro.
SiO_2	60·38
Al_2O_3	13·75
Fe_2O_3	5·33
FeO	3·54
MgO	1·17
CaO	5·23
K_2O	2·29
Na_2O	4·09
H_2O+	2·15
H_2O-	1·03
CO_2	0·02
TiO_2	0·68
P_2O_5	0·18
MnO	0·20
BaO	0·03
	100·07

[1] Analysis by T. Marrack, M.Sc., A.R.S.M.

Granodiorite.—Three outcrops of granodiorite have been mapped by the author.[1] The biggest has an extension of three and a half miles in a north-south direction as seen on the Saingmaw–Hwehka road. It is intrusive into serpentine in the north and into the Tertiaries in the south. Another occurs west of Mawkalon (25° 29′ 55″, 96° 18′ 4″). Its breadth is about half a mile and it extends to a little north of the deserted village of Namlan (25° 28′ 20″, 98° 18′ 51″). Very probably it is continuous with the granodiorite observed a little south of Sietaung, about two miles south-east of Saingmaw (25° 35′ 0″, 96° 17′ 30″). This also is intrusive into the serpentine, which, near the contact, has been rendered schistose. It touches the Tertiaries also in the Hwehka *chaung*, about three-quarters of a mile south-east of Mawkalon (25° 29′ 55″, 96° 18′ 4″) and these have been baked, hardened and are almost vertical near the contact. The third outcrop lies in the Mikilin *chaung* with boulders of breccia of the same rock lying on its surface.

Macroscopically the granodiorite is medium grey in colour, coarse grained and porphyritic in texture. The bulk of the rock is composed of felspars with some quartz and altered hornblende. The felspars comprise orthoclase, andesine and microcline, and have undergone both kaolinisation and sericitisation. Hornblende is brownish in colour and has changed almost wholly into green chlorite, though unaltered cores are occasionally seen. Magnetite occurs as an accessory mineral. Epidote is very commonly developed at the contact with serpentine.

Quartz-diorite.—The most common type has been described above, but basic varieties also occur, *e.g.* a little north of the confluence of the Nammon and Hwehka *chaungs*. They consist of pink felspars, dominantly plagioclase, and black, glistening hornblende with patches of dark fine-textured amphibole and felspar. Quartz is visible in thin sections but is very subordinate, and the rock appears to be a quartz-diorite. The felspar is very largely altered but, however, plagioclase is predominant.

Camptonite.—Fine-grained basic secretions occur and consist of clear laths of felspar with abundant idiomorphic crystals of hornblende, showing bluish green to brownish pleochroism and remarkable zoning. The two minerals seem to have crystallised

[1] *Rec. Geol. Surv. Ind.* vol. lxii, 1929, p. 111.

almost simultaneously. A fair quantity of magnetite is also present. The rock appears to be a basic modification of diorite and may be designated hornblende-camptonite.

Quartz-porphyry.—Small intrusions and injections of quartz-porphyry occur : (1) in the Saingmaw *chaung* about one and a quarter miles south-east of Saingmaw (25° 35′ 0″, 96° 17′ 30″) ; (2) on the Saingmaw–Hwehka road, about a mile east-north-east of hill 1879 ; and (3) in the Kadonyat *chaung* about half a mile west-south-west of Hwehka (25° 28′ 32″, 96° 16′ 43″). Specimens from the first locality show phenocrysts of quartz and felspar with irregular patches of amphibole and chlorite, but the interest lies in the groundmass which is composed of fully or partially developed spherulites embedded in an extremely fine mosaic of quartz and felspar. It is noteworthy that all these intrusions are soda quartz-porphyry and the rock from the last locality, mentioned above approaches keratophyre. A syenite-porphyry, intrusive into serpentine occurs near the deserted village of Sabyl (25° 37′ 27″, 96° 16′ 15″) (92 C/6).

Genetic Relationships.—There seems little doubt that there is a genetic relationship between the granodiorite, quartz-porphyry, quartz veins, rhyolite and rhyolite-breccia of this region. All these are of the same age and undoubtedly represent the intrusive, dyke and extrusive phases of the same cycle of igneous activity.

The volcanic rocks of this region have been described in the chapters on Igneous Activity, chiefly in XXVII, XXIX and XXXII in the companion volume.

The Uru Boulder Conglomerate.

The Plateau Gravels of Upper Burma are represented in the north of the Myitkyina district by a boulder conglomerate, named by the author the Uru Boulder Conglomerate, after the river which was responsible for its formation.

The outcrop of the conglomerate attains to a maximum width of over four miles in the longitude of Mamon, which was formerly very famous for its jadeite workings, and thence it extends to the north and north-east as a belt with an average width of two miles on the right bank of the river. The thickness of the formation must exceed a thousand feet in places, as is

evident from a traverse along any of the tributaries of the Uru, for example, the Sabyi or Mamon *chaungs*. In the case of the latter there is an abrupt descent from Balahka (25° 37′ 30″, 96° 17′ 1″), which is situated on the conglomerate at a little over 2000 ft. O.D., to the valley of the Mamon (Mamaung) *chaung*. The cliffs overlooking the stream are composed entirely of the conglomerate, and no other rock is seen until Hpākān (25° 36′ 38″, 96° 18′ 40″) is reached, near the 806 spot-level on the map, sheet 92 C/6, where crystalline schists are encountered.

The age of the conglomerate is probably Pleistocene to sub-Recent.

The Uru Boulder Conglomerate is strikingly polygenetic, and the older rocks of the neighbourhood are represented by boulders ranging in size from a few inches to several feet. They comprise several varieties of crystalline schists, including mica-, quartz-, glaucophane- and anthophyllite-schists; plutonic rocks of which the chief are granodiorite, diorite and epidiorite; metallic ores including limonite, haematite and chromite; and, most important from the present point of view, boulders of jadeite, for which the formation is worked. It is locally believed that the jadeite of the boulders in the conglomerate is more "mature" than that of Tawmaw. The obvious difference between the two types is due to the removal, during transport, of the skin of weathered mineral in the former case.

Sometimes beds or lenticles of sand-rock occur intercalated in the conglomerate and a specimen hammered from about half a mile west-north-west of Mamon (25° 35′ 10″, 96° 15′ 57″) contains the following minerals along with fragments of quartz- and other schists; quartz, serpentine, chlorite, garnet, hornblende, muscovite, saussurite, etc.

JADEITE-ALBITE ROCKS.

The alignment of the known jadeite outcrops suggests that there are at least four jadeite-albite dykes or sills intrusive into the peridotites and serpentines described above, and they may be designated (1) the Tawmaw dyke, (2) the Mienmaw dyke, (3) the Pangmaw dyke, and (4) the Namshamaw dyke.

The petrological account of these rocks is dealt with in subsequent pages, following the account of the mines.

The jadeite mines of the region can be classified as follows :

1. Outcrop mines.
2. Detrital boulder workings.
3. Jadeite workings in the Tertiary conglomerates.
4. The Uru Boulder Conglomerate workings.
5. Jadeite workings in the Uru *chaung*.

1.—Outcrop Mines.

(a) The Tawmaw Jadeite-Albite intrusion.

Discovery of the Jadeite at Tawmaw.—The biggest outcrop of jadeite is at Tawmaw (25° 41′ 13″, 96° 15′ 28″), and was discovered about 54 years ago. The discovery was purely accidental. The story narrated to the author is that about sixty years ago a hunter named Ninjar of Sanhka reached the site of Tawmaw while hunting, and started cooking rice on a range of stones. One of the stones cracked, and proved to be valuable jadeite. Subsequently the Kachins started mining on the spot. The story recorded by Bateman, Assistant Superintendent, Kamaing, in his diary dated 28th February, 1907, is slightly different. " Some 26 years ago a Kachin who was on a hunting expedition shot at and wounded an elephant. He tracked the elephant to the spot now being quarried and found the animal dead there. He had removed its tusks and was trying to knock some of the flesh off them on a hard rock close by, when the weight of the tusk broke off a fragment of the rock which proved to be a valuable bit of jade. After a fashion, the development of this area has gone on since." The length and width of the proved outcrop at Tawmaw are a little over 300 and 200 yards respectively. The intrusion has been regarded as a dyke, but it is quite probable, as especially seen in the Kadondwin and elsewhere, that the injection took place in the form of a sill. The thickness is very irregular, probably depending upon the fissure into which the jadeite-albitite mass was intruded. The general trend is north-east–south-west which, however, swings between north-north-east–south-south-west and east-north-east –west-south-west.

Old Kachin Workings.—Many old Kachin workings are to be seen to the south-west of the Dwingyi (big mine). When the jadeite was first discovered here at Tawmaw there were only three or four feet of overburden in places, and the covering of serpentine was practically absent. The depth of the numerous deserted pits seldom exceeds six feet. The abandoned water-races used to sluice away the overburden are still to be seen.

The general section of the intrusion exposed at Tawmaw is as follows: at the top a very thick overburden of red earth represents the soil and subsoil formed by the weathering of serpentinised peridotites which form the country rock into which the jadeite-albitite mass is intrusive. Below the serpentinised peridotites lies a thin, earthy, very light-green chlorite-schist, which is locally called "*byindone*". The latter is underlain by a siliceous cherty mass which, in the mine, has the appearance of schistose serpentine. Below the chert comes an amphibole-schist or amphibolite (locally called "*shin*"). Next to the amphibolite is a banded amphibole-albitite rock which is underlain by albitite, and this in turn, by jadeite. Below the layer of jadeite the relationships of the rocks are seldom visible; in rare sections, however, the sequence may be repeated in the footwall, but albitite is not present as a rule below the jadeite, *i.e.* the latter may be directly underlain by amphibolite. In places albitite is absent altogether, but in others it is absent from the footwall only. It may occur at only one in ten localities, and commonly occurs at the top of the sill. In the Kadondwin, in the hanging wall albitite occurs in the middle and jadeite is found above and beneath it, while in the footwall jadeite occurs in lenses in the albitite.[1]

Outcrop Mines of Tawmaw.

The outcrop mines are situated at Tawmaw. There are two of these: (1) the Dwingyi (meaning "big mine"), and (2) Kadon dwin ("*dwin*" in Burmese means a mine).

The Dwingyi.—The Dwingyi is certainly the more important of the two and the mine really consists of shafts and tunnels driven along the jadeite "dyke". There are six shafts in all, and in 1927 the mine subsided in one place making the total

[1] *Rec. Geol. Surv. India*, vol. lxii, 1929, p. 55.

number of surface openings seven. The shafts were originally put down by different people and are named after them.

In addition, there are a few small deserted pits which represent attempts at winning jadeite in the past. About 200 yards south-west of the Dwingyi, numerous old Kachin workings are to be seen. At this site jadeite was found almost at the surface ; only three or four feet of over-burden had to be removed to reach it. Serpentine was practically absent. The depth of these pits did not exceed six feet.

Methods of Mining.—The mines are worked for only about three months in a year, *i.e.* from March to May, and all mining activity ceases with the advent of rains. During the rainy season the mines get filled up with water, and as a result the first operation when work is recommenced is to pump out this water. This is commenced in November or December and continues till the end of February. It may be noted in passing that since A. W. G. Bleeck's visit in 1907, mining methods have changed considerably. Kachins then emptied the mines by removing water with kerosene tins, but nowadays draining is performed by a steam pump.

The next operation is to clean the mines, *i.e.* to remove mud, etc., which has settled below water level. This is done by hauling it up in small petrol tins. When the mine is properly cleaned, operations can be started. The owners of the Dwingyi installed a compressed air drilling machine with which they work thin star-bit jack-hammer drills. Generally the drills are four-rayed, but sometimes they are six-rayed with a maximum diameter of one and three-quarter inches. A hole about six to nine inches in depth is drilled in the jadeite, and then pieces of jadeite are broken off by driving a wedge into the hole with big hammers. But when the compressed air-drilling machine is not operating the miners then work only with blunt chisels, wedges and hammers. The wedges are five inches in length and two inches in breadth. It is noteworthy that jadeite is a very tough and hard mineral and it is extremely difficult to break it. In a few minutes a chisel or wedge loses its sharp edge.

The primitive method of cracking jadeite with burning charcoal still continues. This practice is very injurious both to the mineral and to the miner. The former gets calcined as a result

of this treatment while the value of the stone is considerably reduced on account of the development of cracks in it. The fumes of carbon monoxide emitted from the charcoal fires have their poisonous effects on the miners working underground.

Kadon Dwin.

The Kadon dwin is run on more scientific and up-to-date methods by Mr. C. W. Chater of the Burchin Syndicate. The main vertical shaft, which is about fifteen feet square and fifty feet deep leads to drive No. 1, which is one hundred feet long 30° north of east and represents the hanging wall of the jadeite dyke. It opens out into a winze about 23 feet in depth and this leads to the stope No. 2 which represents the footwall of the dyke and is about 50 feet in length 10° east of north. The main shaft is entirely in serpentine and the drive No. 1 really represents the worked-out portion of jadeite along with the contact rocks, *viz.* " chloritic schist " and amphibolite in the hanging wall of the dyke. The average thickness of the jadeite here was about 4 feet. The winze or shaft No. 2 is entirely in albitite and the stope No. 2 has been driven in the footwall of the dyke. The albitite is traversed by vertical joints and these in some cases are filled with white veins. It is underlain by amphibolite and beneath this is the jadeite, the thickness of which varies from 5 to 7 feet. It is remarkable that the jadeite in the footwall occurs in the form of lenses. Up to 1928 three lenses have been worked out and at the close of the working season in May 1929 the fourth was being opened up. Amphibolite, and albitite with some albitite-breccia intervene between the successive lenses of jadeite. Below the latter come amphibolite and chloritic schist one beneath the other, and serpentine forms the bed-rock. The working face in 1929 was about 21 feet in width and on the left side, breccia, in which crushed fragments of jadeite, amphibolite and albitite are set in a calcareous matrix, was to be seen. The jadeite was seen dipping 30° east at the working face.

Methods of Mining.

To pump out water a 12 H.P. Cochran boiler and pump with 5 inches suction and delivery pipes are used. Drilling is carried

out with compressed air. To work the compressor, both steam- and oil-engines have been installed. These are also used for sawing timber employed in the mine and as firewood in the boiler. Star-bit pneumatic jack-hammer drills are employed, and holes generally 6 to 9 inches, but rarely 18 inches deep, are bored. Subsequently the rock is blasted with dynamite. As far as possible drilling is done in the country rock to expose the jadeite which is then broken down with wedges fixed in shallow bore-holes or with electric blasting wherever necessary.

During the working season water is pumped out of the mines thrice daily and the drilling is carried on day and night. At the time of the author's visit three compressed air drills were being worked by 5 coolies. The depth of the holes bored varies from 12 to 20 inches, but averages about 15 inches. Jadeite is a very tough mineral and C. W. Chater informed me that in one hour of drilling only 2·15 inches of jadeite can be bored. It therefore takes practically one shift drill of 8 hours to bore one hole. Generally 12 to 13 holes are bored and are then blasted with dynamite. Both jadeite and country-rock are hauled up in a skip worked by a steam hoist on a head-gear. A little truck carries the mineral and the gangue from the head-gear into the paddock and the dumps respectively.

Industry declining at Tawmaw.—The mining industry at Tawmaw is gradually declining, chiefly on account of the increasing depth of the mines ; further, the old primitive methods of the Kachins cannot successfully cope with the present day condition of the mines. Unsettled conditions in China, the main consumer of jadeite, must be also partly responsible. The mines, in order to be productive, must be run on scientific and commercial lines, which requires capital, much beyond the means of poor Kachins. It is true that about 20 years ago, the output of jadeite was much greater than at present and three Mawoks (headmen), a Kachin, a Shan and a Chinaman had to be maintained. Even about five years ago, 400–500 miners were working at Tawmaw, but in 1927 and 1928, however, only some 50 to 60 miners had been engaged.

On the Tawmaw alignment are situated the three other outcrops of (1) Sarmamaw, (2) Malinkamaw, and (3) Sanhkamaw.

Sarmamaw.—It is interesting to record the discovery of the following outcrops of jadeite, hitherto unknown to science. About one mile south-west of Tawmaw (25° 41′ 13″, 96° 15′ 28″) is the outcrop of Sarmamaw which occurs on the right bank of a small stream called Sarma *hka,* named after the Kachin Sawbwa of the neighbourhood of Mogaung. At the top is an overburden 10 feet 2 inches thick and there is an inner pit about 13 feet deep with a diameter of about 10 to 15 feet. The jadeite appears to be bedded, dipping north-west, and a set of joints is developed at right angles to the bedding. In places the joints are only about one or two inches apart. At the top jadeite has altered to a soft whitish material, and the local Kachins, who tried to work this deposit, did not go deeper than the surface weathered material and deserted the locality considering that the " jadeite had not matured".

Malinkamaw.—Another locality where a jadeite outcrop was found is called Malinkamaw and is about 2 miles north-east of Tawmaw (25° 41′ 13″, 96° 15′ 28″). The rock here has greenish black inclusions of amphibole. The overburden measured only about 8 feet. Jointing in the north-easterly direction is well marked, and simulates bedding.

Sanhkamaw.—The third locality is situated in the Sanhka *hka*, about 2¾ miles north-east of Tawmaw. This locality does not leave a shadow of doubt as to the intrusive nature of the jadeite into serpentine. The thickness of the serpentine at the top is about 12 feet, and this is underlain by a soft chloritic schist about 1 foot thick. It thins out in a north-easterly direction. The trend of the outcrop here, too, is north-east to south-west with a north-easterly dip of 21°. The serpentine is highly jointed. Numerous small boulders of chromite are scattered about near the jadeite outcrop in Sanhka *hka.*

It appears that the outcrop of Dareemaw (25° 43′ 56″, 96° 18′ 35″) perhaps marks the extension of the outcrop described in the foregoing pages. It occurs near the old Kansi-Tawmaw footpath and there is a big central area with five or six smaller ones in the neighbourhood. At the top there is an overburden of red earth, about 10 feet thick, which is underlain by serpentine. Some rejected boulders of pale green jadeite were seen around the pits.

Another probable outcrop of jadeite lies N.W. of Mienmaw on the path which connects this village with the old Kansi–Tawmaw path. Several boulders of albitite ("*palun*") were seen lying near the pit and apparently the Kachins did not reach the jadeite lying underneath the albitite.

(b) The Mienmaw dyke.

On the Mienmaw dyke are situated the outcrops of Shammonmaw (25° 43′ 39″, 96° 20′ 40″), Mienmaw (25° 43′ 24″, 96° 20′ 40″), and Sharoinawngmaw (25° 44′ 59″, 96° 20′ 40″). The two extreme outcrops are separated by a distance of 1½ miles in a north–south direction.

Shammonmaw.—The outcrop of Shammonmaw (25° 43′ 39″, 96° 20′ 40″) is marked by two old workings aligned in a north–south direction. The northern one is the bigger and is 70 feet long, 30 feet wide and 25 feet deep and was filled with water at the time of the author's visit. The Kachins call it "Mikehtaingmaw" or "Mai-tingmaw," after the tree of *Mesua ferrea* that grows on these hills.

Mienmaw.—The important locality of Mienmaw (25° 44′ 24″, 96° 20′ 40″) has been worked spasmodically by several people. There is a heavy overburden of red earth with abundant iron concretions, 25–30 feet in thickness, but nothing about the relationships of the rocks of the dyke could be seen since the old workings have been filled up with red earth washed from above; only serpentine and chloritic schist (*byindone*) could be seen in places. In one place chrome-epidote was observed with albitite ("*palun*") and this is a favourable indication of the occurrence of green jadeite in the vicinity: chrome-epidote is formed where chromite is present in serpentine, and the associated minerals, albite and jadeite, are coloured green as a result of absorption of the epidote.

Sharoinawng-maw.—The workings of Sharoinawng-maw (25° 44′ 59″, 96° 20′ 40″) lie deserted now, though a Chinaman from Hmawlu, near Zeba, worked it for two years some time ago and employed 50 to 60 coolies both here and at Wikhomaw. After his death in China the work had to be abandoned. All that can now be seen is a deep, twenty-foot square tank filled with water.

(c) The Pangmaw dyke.

The third dyke with a N.W.–S.E. extension for a little over three quarters of a mile comprises the outcrops of Pangmaw, Wikhomaw and Kyobatmaw.

Pangmaw.—The old workings known as Pangmaw are found 80 paces N.E. of the Pang *hka*, where it is crossed by the Namshamaw–Mienmaw path, where ten small deserted pits are to be seen. Jadeite and albitite are both found here with inclusions of amphibole. The serpentine is rendered fibrous near the contact, and occurs as detached boulders around the pits. In the neighbourhood of the jadeite workings chromite and iron-ore boulders also occur in a small water course.

Wikhomaw.—About half a mile N.W. of Pangmaw 13 old pits are to be seen, which mark the jadeite outcrop of Wikhomaw. About four years ago, as mentioned above, a Chinaman from Hmawlu mined it for three years. The biggest pit, which is really a combination of three smaller ones, is about 60 feet in length in a north-north-east–south-south-west direction. The breadth of the workings is 32 feet.

At the top there is an overburden of red earth about 6 feet in thickness. It is underlain by schistose and talcose serpentine. The pit is 18 feet deep, but at the bottom 3 feet of water covers the jadeite zone. A little to the west of this pit there is a small dry stream, where jadeite is exposed dipping west in the same direction as the serpentine.

Kyobat-maw.—The old workings of Kyobat-maw are about one quarter of a mile north-west of Wikhomaw. Besides several small deserted pits there is a long trench cut in the serpentine, about 100 yards in length, 10 feet in width and about 25 feet in depth in places. The trend of the cutting is east–west but in places swings between E.N.E. and W.S.W.

(d) The Namshamaw dyke.

The following outcrops of jadeite are situated in the neighbourhood of Namshamaw (25° 45′ 31″, 96° 22′ 28″):

(1) Namshamaw.
(2) Mawsitsit.
(3) Wayntmaw.

This dyke[1] strikes in the same direction as the Pangmaw dyke, with a W.N.W.–E.S.E. trend.

Namshamaw.—The jadeite workings of Namshamaw are situated near the confluence of the Namsai and the Uru *chaung*. Blocks of jadeite of irregular shape, which seem to have travelled little, occur in red earth formed by the decay of the serpentine. Very likely the jadeite boulders excavated here represent disintegrated portions of a dyke which has either not been exposed yet or lies a little to the west. Early in 1929 Chinamen were working for jadeite here.

A little to the north of Namshamaw lie the deserted workings of Konfimaw, marking an occurrence of red jadeite (*konpi*).

Mawsitsit.—The deserted workings of Mawsitsit lie about half a mile west (slightly north) of Namshamaw in a stream and adjoining it. The old pits are lying filled with deep water, thereby concealing the relationships of the rocks. The local people recognise two varieties :

1. *Mawsitsit* (chromo-jadeite) of dark green colour.
2. *Kyet tayoe* (chrome-garnet) bright green colour.

Of the two, *Mawsitsit* finds most favour as a semi-precious stone.

Wayutmaw.—The jadeite outcrop of Wayutmaw is about a quarter of a mile west-north-west of Mawsitsit.

At the top there is an overburden about 6 feet in thickness which overlies the weathered jadeite, and the mines apparently did not go much deeper than that. A number of old pits are still to be seen. Fairly big boulders of chromite were observed near this locality.

2. Detrital Boulder Workings.

Two localities in the neighbourhood of Tawmaw were worked for detrital jadeite boulders in the past : (1) Pan Din Maw (25° 41′ 17″, 96° 16′ 23″), (2) Paim-ma-chait (25° 38′ 51″, 96° 15′). These very shallow or almost surface workings deserve separate treatment, since they constitute a class by themselves.

(1) **Pan Din Maw.**—The jadeite-bearing locality of Pan Din Maw was discovered by a Kachin about 20 years ago, it was

[1] Term used in general sense.

worked for only one year about six years ago, but as valuable mineral was not found in any quantity, the pits were deserted. The latter can be approached by a wood-cutter's path, bifurcating from the main Tawmaw-Lonkin road, a little over a furlong E.S.E. of mile 41, marked on the map (92 C/6). A number of very shallow pits are to be seen on the left bank of a small un-named stream, flowing W.N.W.–E.S.E., which are a little over a mile E.N.E. of the spot where the path leaves the main road.

The pits are only 2 to 3 feet deep and no jadeite occurs at a depth of 4 feet. It is found in the form of partially worn boulders along with those of serpentine. It is very likely that these boulders were detached from the dyke exposed at Tawmaw and transported for some distance before being embedded in the red earth of their present home.

(2) **Paim-ma-chait.**—The second locality is situated about 2½ miles S.S.W. of Tawmaw, and lies one-third of a mile north-west of the Tawmaw–Lamong road. About 30 years ago Kachin hunters discovered this place and some 20 years ago it was the scene of mining activity for one year, but it was ultimately abandoned for the same reason as Pan Din Maw.

Between 40 and 50 old pits are to be seen and their diameter varies between 3 and 4 feet, the maximum in rare cases being 6 feet. Their depth varies from 3 to 4 feet and in rare cases it is as much as 6 feet. They are all on the right bank of the Paim-ma-chait *chaung* and boulders of jadeite are also found in the bed of the stream itself. Jadeite, as in the previous case, is found in the form of boulders and to test the quality of the stone, they were broken with hammers; very big ones were cracked with fire. Amphibole occurs as inclusions in the jadeite. I was told that only one stone, of the value of Rs. 180/-, was found along with a number of smaller ones valued at about Rs. 20/- each. A number of chromite boulders were discovered scattered in the stream.

3. Jadeite workings in the Tertiary Conglomerates.

A. In the neighbourhood of Kansi (25° 47′ 1″, 96° 22′ 48″) the following workings occur: (1) Pangmamaw, (2) Mutan-

tumaw, (3) Samhtanmaw, (4) Shilamaw, (5) Sanimaw, (6) Aungbilemaw and (7) Hpelaimaw.

All these workings except the last, which was not visited by the author, lie in the Tertiary conglomerates, and the torrential streams descending from the neighbouring hills of serpentine with jadeite must have been responsible for their deposition.

(1) **Pangmamaw.**—The old workings of Pangmamaw are to be seen in the Pangma *hka* and its tributaries. Kachins worked the banks of the stream and sometimes the adjoining ground for boulders of jadeite in the past. The workings are situated in the Tertiaries, which comprise soft, bluish, greenish and yellowish sandstones, shales, coarse grits and conglomerates. The last include both coarse and fine varieties, and quartz, quartzite, schists, serpentine and chromite take part in their constitution. Some of the boulders of serpentine are huge in size and must have been derived from the hills on the east where the Pangma *chaung* takes its source; but the Tertiaries must have been in position prior to the establishment of the present drainage system.

Some of the jadeite boulders found here, according to local information, were huge—about the size of a buffalo—proving thereby that the boulders had not travelled far from their original source.

(2) **Mutantumaw.**—One of the main tributaries of the Pangma *chaung* is called the Mutantu *hka* and hence the name of the workings. These workings have been deserted, though formerly Kachins, Shans and Chinese worked here. It is reported that the quality of the jade is not good and is rather scarce.

(3) **Samhtanmaw.**—The workings of Samhtanmaw lie in a small tributary stream (of the same name) of the Pangma *hka*, which joins the Uru river near Kansi.

(4) **Sanimaw.**—The workings of Sanimaw are situated in the Sani *hka*, east of Kansi. The overburden, about 6 feet in thickness, is underlain by the boulder bed, about 4 feet in thickness, consisting mostly of partially worn boulders of serpentine and crystalline schists. The boulders of jadeite itself are angular and irregular in shape showing that they have not undergone much transport. Several old pits are to be seen in the neighbourhood of the stream.

(5) **Shilamaw.**—The workings of Shilamaw lie in the stream of this name which joins the Uru river below Kansi.

(6) **Aungbilemaw.**—The old jadeite workings known as Aungbilemaw lie in the lower course of the Seintu *hka.*

B. In the neighbourhood of Lonkin (29° 39′, 96° 22′).

(1) **Kademaw.**—The workings of Kademaw (25° 39′ 17″, 96° 20′ 23″) lie near the unimportant Kachin village of Namayang near the 34th mile marked on the Kamaing–Tawmaw road. The mining is carried on along the banks and in the vicinity of the Namayang *hka.* At the top there is generally an overburden of alluvium that is underlain by the Boulder Conglomerate, which is mined for boulders of jadeite. The Chinese in 1929 carried on some underground mining, by way of driving tunnels.

(2) **Mawmaik-ak.**—The workings of Mawmaik-ak are situated on both sides of the Namayang *chaung* between Kademaw and Masamaw, just before the schists crop out in the stream.

(3) **Masamaw.**—The workings of Masamaw (25° 39′ 33″, 96° 19′ 58″) are to be seen adjoining the left bank of the Masa *hka* which is an important tributary of the Ningma *hka.* As usual there is an overburden consisting of red earth capping the conglomerate. Mining is carried on by means of *mayaws* during the rainy season. The overburden is sluiced away by booming with water obtained from springs and small streams issuing from the sides of the hill. As is to be expected the thickness of the overburden increases as we recede from the Masa *hka.* It is remarkable that they are redigging the old pits. Formerly they went only about 12 feet in depth, in 1929 they had gone about 25 feet deep and were still continuing.

From the disposition of the Tertiary jade-bearing conglomerate in the neighbourhood of Masamaw and elsewhere it is apparent that the great bulk of it must have been deposited by torrential streams from the adjoining hills flowing into the Uru *chaung.* Similarly the torrential streams with the Uru *chaung* must have played an important part in the deposition of the Uru Boulder Conglomerate. (See p. 41).

(4) **Maraw-maw.**—This is a new locality worked in 1929 and lies about 150 yards north-north-west of the Kachin village of

Marawgahtaung (25° 38′ 49″, 96° 19′ 36″). The workings lie on the hill-slope adjoining the right bank of the Ningma *hka*. At the time of the author's visit in November 1928 not a single pit was to be seen; but on his return in the beginning of May 1929 he found at least one thousand deserted pits. A few Kachins and Shan-Burmans were still working. During the 1929 season four stones of the value of a few thousand rupees had been found besides several others of smaller value. The thickness of the Tertiary boulder conglomerate here is rather small and the bed-rock, viz., the schists, appears close to the surface. Some of the pits are hardly 4 feet deep. Lower down almost all the pits have been dug in the schists with obvious results. On both banks of the Ningma *hka* some old pits were to be seen, some in the schists and a few in the boulder conglomerate adjoining the stream. In all about half the total number of pits had been dug in the schists with no return whatever for money, time and labour.

The material for the jadeite-bearing boulder conglomerate apparently came from the serpentine deposits of Tawmaw; and the epidiorites and quartz boulders, which constitute the rocks immediately adjacent to the conglomerate, are predominant in its constitution.

(5) **Maw-sisa.**—The workings of Maw-sisa mostly lie in the bed of the stream of this name which joins the Uru river about $\frac{3}{4}$ mile south of Warong village (25° 39′ 13″, 96° 21′ 15″). These workings start from the junction of the Uru and the Maw-sisa *chaung* and continue for about a mile inwards. The pits are rather shallow, since the hard, consolidated conglomerate makes its appearance very near the surface. Old deserted *mayaws* (water-channels) are to be seen in places.

It is remarkable that as soon as hard consolidated conglomerate is reached, which cannot be mined with crowbars and picks, mining is stopped. It would be worth while to prove favourably or otherwise the presence of boulders of jadeite in this hard conglomerate as well, otherwise for want of better organisation and modern mining methods vast reserves of jadeite may remain buried for a long time to come.

(6) **Saung Chein-maw.**—Some old pits are to be seen at the confluence of the Saung Chein and the Uru *chaungs*.

(7) **Ngopinmaw.**—The workings of Ngopinmaw are seen about a quarter of a mile north-east of Kademaw on the way to Sanhka (25° 41′ 8″, 96° 20′ 57″).

(8) **Sanhkamaw.**—The numerous old jadeite workings of Sanhkamaw are situated near the Kachin village of Sanhka (25° 41′ 8″, 96° 20′ 57″), in the area enclosed by the U-shaped bend of the Sanhka *chaung* near its mouth. They also extend along the Sanhka *hka* for a distance of about one mile from its confluence with the Uru river. Old workings also occur in the lower course of the Wage *hka* which joins the Sanhka *chaung* about a quarter of a mile south-west of Sanhka.

C. In the neighbourhood of Hwehka.

Tertiary jadeite workings exist in the neighbourhood of Hwehka within a radius of about 2 miles (see Fig. 2). As stated above, bands of conglomerate embedded in the Tertiary sandstones and shales are mined for jadeite (see Plate II, Fig. 2), in a number of places, the names of which are given below :

D. In the neighbourhood of Kadonyat (25° 3′ 20″, 96° 15′ 46″).

1. Mabu-maw (north-west of Kadonyat), in the Mabu *chaung*.
2. Sawbwagyaungmaw (deserted). These old workings lie in a small tributary stream of the Kadonyat *chaung*, about one-third mile north of Kadonyat.

E. In the neighbourhood of Hwehka (25° 29′ 3″, 96° 16′ 43″).

3. Hwehkamaw, situated in the neighbourhood of Hwehka village.
4. Hmawlugyaung-maw. These workings are situated in a small dry stream, west of Hwehka village.
5. Sanimaw.
6. Hmowtaung. These quarries have a working face about 30 feet high and near the crest of the hill, about half a mile north of the present Rest House of Hwehka. One old underground working was seen—which had fallen in.
7. Mawnanhka (deserted).

The workings No. 6, 7 and 8 are situated on the hill north of Hwehka.

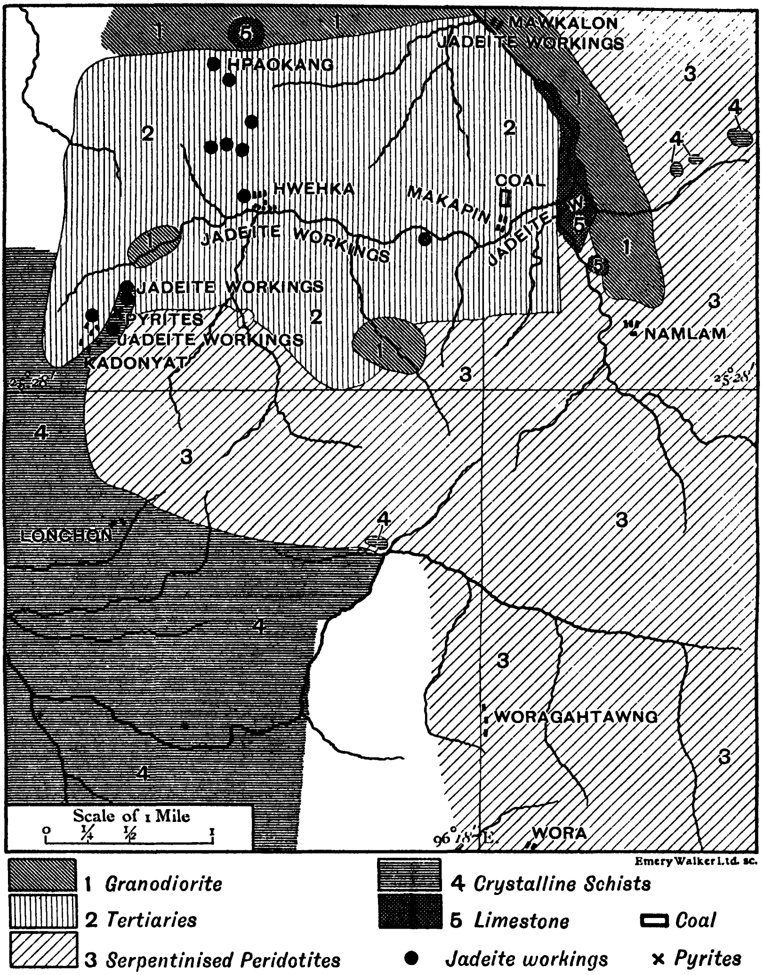

FIG. 2.—Sketch map showing jadeite workings in the neighbourhood of Hwehka.

8. Natyedwin is situated a little north-west of Hpaokang village, close to the Mamon-Hwehka road. Only one pit was being worked at the time of the author's visit.

9. Ohminwa-maw (deserted), situated in the stream of the same name.

F. In the neighbourhood of Makapin. (25° 28′ 53″, 96° 18′ 4″)

10. Zibyugon (25° 28′ 45″, 96° 17′ 41″), about a mile east of Hwehka on the right bank of Hwehka *chaung*; worked throughout the year. A very interesting section of the Tertiaries is exposed in these workings. At the top there is a wash from the Tertiaries mostly of a conglomeratic nature, about 22 feet thick, which is underlain by weathered sandstone, yellowish in colour having a thickness of 2 feet 2 inches. Below this comes a clay which is pebbly in places while pieces and small stumps of lignite are arranged in rows in it. It overlies the main jadeite-bearing conglomerate which has a thickness of about 3 feet and is succeeded by hard coarse sandstones, locally called " Phah " (meaning bed rock). This is too hard for the miners to quarry.

11. Mawgyaungwa (deserted). These old workings exist in the Mogyaung *chaung*, a tributary of the Hwehka *chaung* which joins the latter from the south, a little west of Makapin.

12. Makapin. These workings are said to be the oldest and according to the local inhabitants, the best jadeite comes from them.

13. Namlanmaw, comprises a few pits in a small dry stream east of Makapin, which forms the Makapin-Namlan footpath. They are only worked during the dry season.

14. Satpya-maw (deserted), situated close to the confluence of the Satpya and Hwehka *chaungs*.

15. Mawnantee, situated between Mawkalon and Satpyawa and worked only during the dry season.

G. In the neighbourhood of Mawkalon (25° 29′ 55″, 96° 18′).

16. Nankatmaw, near Mawkalon, worked throughout the year.

17. Metlinwa-maw (deserted), near Mawkalon.

18. Mawkalon (see Plate II, Fig. 1). This is the biggest centre of mining activity in the vicinity of Hwehka at the present day and the industry is continued all the year round.

19. Uke-maw. These workings lie in the Uye *chaung* which meets the Hwehka *chaung* from the west near Mawkalon. They are worked throughout the year, but more especially during the rainy season.

PLATE II.

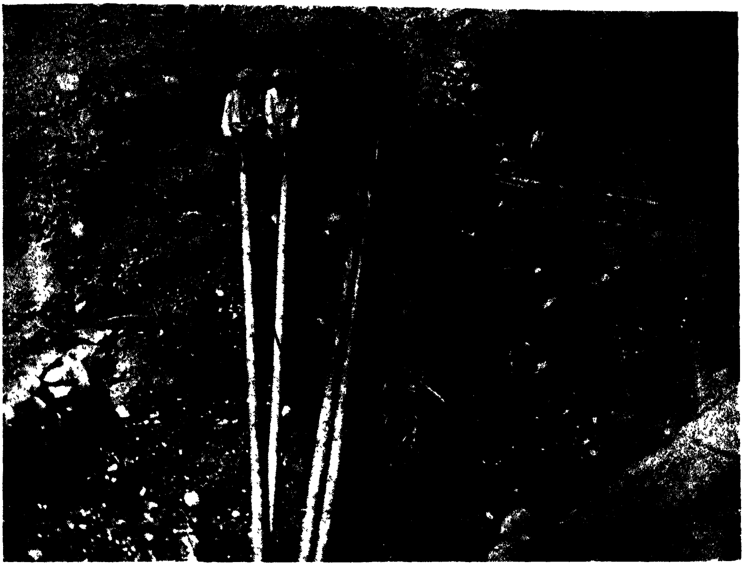

FIG. I.—A JADEITE-WORKING AT MAWKALON IN THE BED OF THE STREAM.

Notice the digging of the boulder conglomerate. The useless boulders and débris are dumped away on the sides of the working, and the water is pumped out by means of bamboo pipes.

20. Patit-maw, north of Mawkalon in the Hwehka *chaung* is worked only during the dry season.

In the vicinity of Hwehka the slopes of the hill north of the village are being worked (see Plate II, Fig. 2). It appears that quarrying was commenced at the base of the hill and has gradually proceeded upwards until at the present day the Kachins are working almost at the top, about 550 feet above the bed of the Hwehka *chaung*. Huge dump-heaps and numerous deserted workings are to be seen on the road to the present workings. The different claims which are generally 16 feet square or 10 by 20 feet in extent are defined by bamboo barricades propped by wooden posts, to prevent the collapse of the sides, composed of rather loose sandstones, shales and conglomerate of the adjacent claims. These workings are in the nature of shallow wells. Sometimes open quarrying is also done and the working face is about 18 to 20 feet high. The bands of jadeite-bearing conglomerate, as remarked already, are intercalated in the sandstones and shales. Sometimes a number of these bands are present, for example, at Sani-maw there are three bearing distinctive local names.

The lowest layer is the most productive. The thickness of the conglomerate bed varies from 1½ to 6 feet. Sometimes the boulders forming the conglomerate are of huge size, a few feet in diameter. It is very remarkable that the Tertiary conglomerate is very rich in serpentine, and the name serpentine-conglomerate would not be a misnomer.

Methods of mining.—The methods of mining in this area are almost the same as in the case of the Uru Boulder Conglomerate workings. Here too both the hill sides and river-bed workings exist, but the former are more numerous.

Mining, as usual, is done with crowbars and *mamooties*. In some claims four men work together: one of them does the digging with a crowbar, the second fills up the baskets and the remaining two dump the débris. For bailing water bamboo pumps (see Plate II, Fig. 1) are used, but at Sanimaw the tedious process of removing water in kerosene cans still prevails. In places a sort of lever lift is used for hauling up the débris from the pits.

With regard to the source of the jadeite found in the Tertiary

conglomerates of Hwehka, the author has concluded that the stone cannot possibly have come from the Tawmaw dyke and that there must have been another primary occurrence of the mineral associated with the peridotites and serpentines of the south, which has either been denuded away or lies concealed in the impenetrable jungle.[1]

4. The Uru Boulder Conglomerate Jadeite-Workings.

The Uru Boulder Conglomerate is worked for jadeite in numerous places and these workings can be classified as follows:

1. Stream-bed workings, where mining is possible throughout the year.
2. Hill-side workings, where the rock is quarried during the rains, which help in sluicing away the overburden and the matrix of the conglomerate. These hill-side workings exist in the neighbourhood of Balakha (25° 37′ 30″, 96° 17′ 1″), the deserted village of Manna (25° 36′ 43″, 96° 16′ 15″), Nammaw (25° 38′ 20″, 96° 15′), etc.

Stream-bed workings for jadeite are really too numerous to mention and are situated on the banks or in the bed of the Uru *chaung* and its tributaries. They commence from near Kansi (25° 46′ 54″, 96° 22′ 47″) and continue intermittently right down to Haungpa.

The following section is generally observed in the Boulder Conglomerate workings for jadeite.

I. Alluvium at the top, of variable thickness.

II. A layer of pebbles and gravel which the miners call "*Kadi Kyaw.*"

III. Boulder Conglomerate, which is locally called "*Kyauk Kyaw.*"

IV. Sand-rock with boulders, locally known as "*Thai Kyaw,*" which is generally gold-bearing and, according to the miners, jadeite boulders of better quality are found in this layer. When this layer is absent, it is thought the place is not worth working, and valuable finds are not expected.

V. Bed-rock, locally called "*Phah*" and all mining is stopped when it is reached. Jadeite boulders are found only in III and IV.

[1] *Rec. Geol. Surv. Ind.* vol. lxii, 1929, p. 57.

PLATE III

A JADEITE-WORKING IN THE URU BOULDER CONGLOMERATE, PAN-TINMAW, OPPOSITE THE CONFLUENCE OF THE URU AND THE MOWMOAN *CHAUNGS*

In the neighbourhood of Hpakan (25° 36′ 38″, 96° 18′ 40″). Hpakan is an important mining centre and workings for jadeite exist in several neighbouring localities listed below:

1. Pantinmaw, opposite the confluence of the Uru and the Mowmoan *chaungs*. Here some fine typical sections of the Boulder Conglomerate are to be seen (see Plate III).

2. Monyin Chan, about 1⅓ miles east of Hpakan on the right bank of the Uru *chaung*.

3. An-ma. These workings are situated ⅝ths of a mile east of Hpakan on the left bank of the Uru river. There is a thick capping of alluvium, 14 ft. thick, at the top of the Boulder Conglomerate and the thickness of the latter is 9 feet. At the time of my visit women were washing for gold here.

4. Mowmoan *chaung*, near Mowmoan village (25° 36′ 53″, 96° 19′ 11″) and in the lower course of the stream of the same name.

5. Mowmoan Chaungbya (upper workings). Jadeite workings extend right up to the source of the Mowmoan *chaung* and in some of its tributaries.

6. Mow-Maung, in the stream of the same name, north-west of Hpakan (25° 36′ 38″, 96° 18′ 40″).

7. Shulunghka. In the neighbourhood of Shulunghka (25° 36′ 23″, 96° 17′ 28″) there are both stream-bed (in Sabyi *hka*) and hill-side workings. From the number of deserted pits and water-leads seen here it appears that jadeite mining must have been more flourishing years ago than it is at the present day.

8. Kalamaw (25° 36′ 55″, 96° 16′ 55″). These workings are situated a mile above Shulunghka and lie in the Sabyi *hka* stream. Old iron pipes are still to be seen lying about here. The village is surrounded by high steep cliffs of the Boulder Conglomerate on all sides.

9. Sabyi and Sabyi Wa (25° 37′ 24″, 96° 16′ 15″) (both deserted).

10. Hpakangyi. A little over one-third of a mile E.S.E. of Hpakan (25° 36′ 38″, 96° 18′ 40″), on the left bank of the Uru *chaung*. Opposite these workings are precipitous cliffs about 200 ft. high above the level of the river bed.

11. Mowtaung, a little below Hpakangyi.

In the neighbourhood of Sankywe (Sanchoi) (25° 35′ 25″, 96° 17′ 47″)

12. Sankat, about $\frac{7}{10}$ths of a mile—some 5° west of South of Hpakan, on the right bank of the Uru *chaung*.

13. U-mar, about $\frac{4}{5}$ths of a mile N.E. of Sankywe (25° 35′ 25″, 96° 17′ 47″) on the left bank of the Uru *chaung*.

14. Sankywe (marked Sanchoi on the map, 92 C/6).

In the neighbourhood of Parpyin (25° 35′ 21″, 96° 16′ 40″).

15. Mena-aik, a little over $1\frac{1}{2}$ miles E.N.E. of Mamon (25° 35′ 10″, 96° 15′ 57″). This locality was once worked for gold in addition to jadeite.

16. Nampagon, a little above Parpyin.

17. Parpyin. In one pit near the stream the following section was observed :

3. Sandy alluvium, false-bedded - -	9 ft.
2. Fine gravel-bed - - - -	2 ft.
1. Boulder-bed, mined for jadeite -	19 ft.

In the neighbourhood of Mamon (25° 35′ 10″, 96° 15′ 57″).

18. Thabeymaw, about half a mile north-east of Mamon (25° 35′ 10″, 96° 15′ 57″) on the right bank of the Uru *chaung*.

19. Mamon, in the neighbourhood of the village of Mamon.

20. Meikkye.

21. Htintingyi.

22. Htingtingale.

23. Sabwe, in the Sabwe *chaung*.

The workings 20–22 all lie along the Uru *chaung* below Mamon.

In the neighbourhood of Nammaw (25° 38′ 20″, 96° 15′).

24. There are several important jadeite workings in the neighbourhood of Nammaw.

In the neighbourhood of Haungpa (25° 30′, 96° 6′ 15″).

The following important workings for jadeite occur in the neighbourhood of Haungpa (Fig. 3).

25. Namasabein.

26. Mawkadi.

27. Tamkhan.

28. Tape.

In this region Tamkhan is the most important mining centre and the area enclosed by the inverted U-shaped bend of the stream (Uru *chaung*) is worked. The mining methods are the same as in the north.

The interesting workings of Sietaung must not be omitted. They are situated about 2 miles south-south-east of Saingmaw (25° 35′, 96° 17′ 30″) or about one-fifth of a mile south-west of the confluence of the Nammaw and Hwehka *chaungs*. This locality was worked for precious stones even during the time of the Burmese kings but was subsequently deserted. About 9 years ago, jadeite mining was renewed and one stone was sold

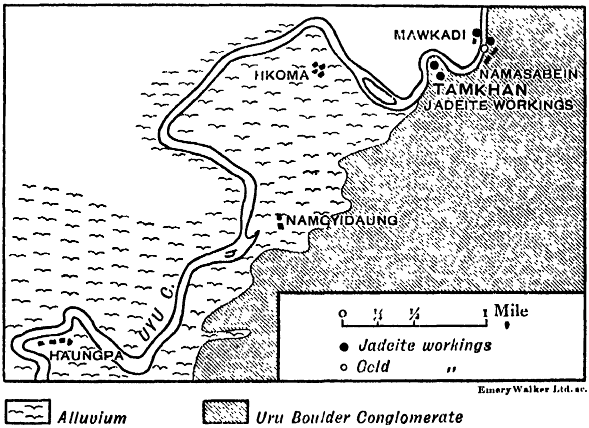

FIG. 3.—Showing jadeite and gold workings in the neighbourhood of Haungpa.

for Rs. 6000/-. There are several deserted pits numbering about 1000. The workings are situated on both sides of the Hwehka *chaung*, however, those on the left bank constitute the majority. The thickness of the Boulder Conglomerate varies from 1½ feet to 6 feet at the most. In 1929 only one pit was being worked in which the overburden constituted 13 feet 5 inches, underlain by a boulder-bed 6 feet in thickness, which overlies the serpentine forming the bed-rock; but a comparatively larger number of people are engaged in the industry during the rainy season. It appears that this Boulder Conglomerate was deposited by the Hwehka *chaung* since it disappears at a distance of about 100 yards from the stream. The

nature of the boulders is also different from those seen towards the north the majority of them being of granodiorite, diorite, granophyre and quartz.

Methods of mining.—Before commencing mining, Jade-Nats (Spirits) are propitiated by almost every worker, irrespective of his nationality. It is believed that if the *Nats* are pleased, the miners will make valuable finds quickly.

Generally, at the top is some overburden (alluvium), which is sluiced away by a water-race formed by diverting the channel of a stream. Then the Boulder Conglomerate is quarried with picks, crowbars and *mamooties*, so that a steep face is obtained. Water dammed a little upstream is made to flow as a race over this steep face, which washing away all the earth, leaves the boulders clearly exposed to view. They are carefully examined for jadeite. If water is not available from the stream, then a pit is dug in its bed, and it is replenished from the Boulder Bed. Then it is pumped out by an ingenious contrivance, described below, on to the desired place. On the other hand, in the bed of the Uru *chaung* and some of its tributaries, water almost invariably fills the pits dug in the Boulder Conglomerate, so that to carry on mining it is necessary to empty the pits. For this purpose a long bamboo is used as a pipe or pump cylinder in which a wooden plunger with a T-shaped handle at the outer end and a leather valve at the inner is worked It is remarkable how it exhausts the water so rapidly. The number of pumps employed in a pit depends on the amount of water to be bailed out. At Mawkalon, in an exceptionally large pit as many as 8 or 9 pumps have to be worked simultaneously.

It must be noted here that the work is not all carried out on up-to-date scientific lines, but in the old primitive fashion. The people work blindly believing entirely in their luck.

The miners are not all scrupulous in selecting the locality they propose to work. In this they are entirely guided by instinct. If in a particular spot, some valuable find is made, almost all the coolies flock to it. Such methods very often result in considerable wastage of labour and money, as no record is kept of the worked-out places. Not infrequently the same spot is dug over three or four times with obvious results.

Another important drawback is that the work is not syste-

matic. Their present methods result simply in picking up the best pieces of jadeite and neglecting entirely the less valuable ones. In fact the whole industry requires reorganisation.

In the Boulder Conglomerate workings every race and nationality is represented. Kachins, Shans, Burmans, Chinese and occasionally an Indian are to be seen: the Shans probably form the majority. The labour is financed by jadeite merchants.

5. Workings in the Uru Chaung.

Occasionally jadeite workings are situated in the Uru *chaung* itself. A stray labourer might search for jadeite boulders from the bed of the stream. This is a laborious task as the man has not uncommonly to stand in water, about thigh deep all the time while, as a rule, the reward of his exertions does not arrive very promptly.

In places the Shans dive in the Uru *chaung* in search of the precious stone. This method is used at Mamon and Chaunglon. The latter locality is about a quarter mile east-north-east of the confluence of the Nammaw and the Uru *chaungs*.

PETROLOGY OF THE JADEITE-ALBITE ROCKS.

The jadeite-bearing intrusions consist of the following three rock types, which grade into one another jadeitite, albitite and amphibolite.

The Jadeitite is an exceedingly tough rock, normally white, but it is irregularly streaked and spotted with emerald-green by chromite, apple-green by iron and lavender-blue by manganese. In some cases the rock is monomineralic, and this is the densest type with a specific gravity of 3·34, and furnishes practically all the precious gem material.

In other specimens large crystals of amphibole are present in addition to the jadeite (see below). Intermediate in composition between the pure jadeite rocks and the albitites are the albitic jadeitites, containing variable quantities of albitite. With decreasing jadeite these grade into albite rocks or albitites.

Chemical Composition.—The range of chemical composition of the jadeitites is indicated by the analyses listed below, which

were prepared for Professor Lacroix by M. Raoult.[1] The calculated analysis of pure jadeite is included for comparison.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SiO_2 -	59·40	59·84	58·18	58·64	58·46	57·48	51·10
Al_2O_3 -	25·25	24·48	21·40	23·50	24·21	21·81	27·55
Fe_2O_3 -	—	—	0·29	0·21	0·48	0·12	0·23
FeO -	—	1·20	2·53	0·85	0·76	1·59	1·28
MnO -	—	—	0·08	—	0·03	0·05	0·08
MgO -	—	0·81	2·65	1·45	0·39	3·21	1·10
CaO -	—	1·42	3·82	1·88	1·74	2·08	2·32
Na_2O -	15·35	11·66	9·95	11·93	12·71	12·35	12·86
K_2O -	—	0·35	0·16	0·55	0·35	0·25	1·22
TiO_2 -	—	—	—	—	—	—	—
P_2O_5 -	—	—	—	—	—	—	0·04
H_2O+	—	0·17	0·50	0·86	0·69	0·55	1·49
H_2O-	—	0·11	0·19	0·36	0·11	0·22	0·45
	100·00	100·04	99·75	100·23	99·93	99·71	99·72
Density	—	3,276	3,348	2,685	—	—	3,284

1. Theoretical jadeite. $NaAl(SiO_2)_3$.
2. Jadeitite with jadeite in long white rods, Tawmaw; analyst, M. Raoult.
3. Apple green jadeitite, Sietaung.
4. Highly albitic part of a jadeitite from Kadon dwin.
5. White jadeite in long white rods. Analyst, Raoult.
6. White jadeite, spotted green, Dwingyi.
7. Nepheliniferous jadeite, Tawmaw.

The normative composition of the above rocks, except No. 5, as given by Lacroix is tabulated below:

	(1)	(2)	(3)	(4)	(6)	(7)
Orthoclase - -	—	2·22	1·11	3·34	1·67	7·23
Albite - - -	64·97	69·17	60·26	60·78	56·07	33·40
Anorthite - -	—	6·95	13·07	8·62	3·34	11·40
Nepheline - -	34·93	15·90	13·06	21·87	26·13	40·68
Corundum - -	—	—	—	—	—	1·02
Wollastonite -	—	2·35	2·44	0·35	3·02	—
Enstatite - -	—	—	1·40	0·20	2·10	—
Ferrous silicate -	—	—	0·92	0·13	0·66	—
Forsterite - -	—	1·40	3·64	2·38	4·13	1·96
Fayalite - -	—	1·73	2·75	1·02	1·53	1·84
Magnetite - -	—	—	0·46	0·23	0·46	0·23

[1] Lacroix, A., "La jadeite de Birmanie, les roches qu'elle constitue ou qui l'accompagnent, composition et origine," *Bull. Soc. franç. Min.*, vol. liii, 1930, pp. 216-254.

Physical Properties.—Prismatic cleavage in Burmese jadeite is very well-marked and partings in several directions are also distinct, including those parallel to (100) and (010).

Interpenetration twinning on a prism face, and simple twinning are observed under the microscope.

The specific gravity of the jadeite ranges from 3·264 to 3·336 and the average of 12 determinations was 3·31. Prismatic, columnar, massive, fibrous, granular and compact habits of jadeite were observed.

Colour.—Jadeite varies from pure white to various shades of green. Not infrequently green spots or streaks are observed in the white varieties. Other less common tints are amethystine, light-blue, bright-red, brownish and black. The bright-red and brownish tints are observed in a thin outer zone of jadeite boulders embedded in red earth, and the colour is due to the dissemination of ferruginous matter by percolating water. About one-third of an inch from the surface the red colour entirely disappears. Thin sections of red jadeite are seen to be stained red and yellow with haematite and limonite respectively.

Microscopic Characters.—Thin sections of jadeite are seen to consist of interlocking, hypidiomorphic, rather irregular prismatic sections. It is this interlocking arrangement of the crystals that makes the mineral so tough. Idiomorphic sections show the development of prisms commonly, and of pinacoids rarely. Sometimes the jadeite shows granoblastic structure, at others, it is mylonitised, and in places radially arranged, sheaf-like aggregates are to be seen. The average double prismatic cleavage angle is 87·3, while it varies from 85·2 to 89·0, depending upon the angle at which the crystal is lying in the section. Jadeite is normally colourless in thin sections, but the bright-green variety exhibits a pale-green colour under the microscope and is very slightly pleochroic. The birefringence is strong. The maximum extinction angle observed is 43·5° while the minimum is 27°. Undulose extinction is very characteristic, indicating that the mineral has undergone considerable strain. Inclusions of amphibole are not infrequent and occasionally those of albite too. The mineral becomes cloudy and opaque on account of meteoric weathering, but under the microscope it is also seen altered to colourless amphibole.

The new analyses 5, 2 and 3 yield the following chemical compositions, expressed in terms of silicate molecules.

	(5)	(2)	(3)
$NaAl(SiO_3)_2$ - -	83·78	77·40	64·80
$NaFe(SiO_3)_2$ - -	1·38	—	0·85
$CaAl_2(SiO_3)_4$ - -	11·86	10·65	20·00
$MgAl_2(SiO_3)_4$ - -	—	7·70	—
$FeAl_2(SiO_3)_4$ - -	—	4·30	—
$MgSiO_3$ - - -	0·97	—	6·65
$FeSiO_3$ - - -	1·43	0·78	4·80
$CaSiO_3$ - - -	0·15	—	2·10

An examination of the analyses shows that the apple-green jadeite of Sietaung (3) has a peculiar composition due to its high content of calcium, iron, and magnesium metasilicates.

The mineral named " tawmawite " by Bleeck is characterised by its dark emerald-green colour, and by an exceedingly strong pleochroism, (emerald-green to lemon-yellow); Bleeck described it as a chromiferous epidote, and gave the following analysis :

SiO_2 - - - -	37·92
FeO - - - -	9·93
Al_2O_3 - - - -	12·83
Cr_2O_3 - - - -	11·16
CaO - - - -	25·35
H_2O - - - -	2·38
	99·57

Recently Lacroix has questioned the existence of tawmawite and refers it to chromiferous jadeite which was analysed by M. J. Orcel with the following results :

SiO_2 - - - -	57·90
TiO_2 - - - -	0·23
Al_2O_3 - - - -	19·40
Cr_2O_3 - - - -	3·75
Fe_2O_3 - - - -	1·37
FeO - - - -	0·06
MgO - - - -	2·82
CaO - - - -	0·75
Na_2O - - - -	13·20
K_2O - - - -	0·40
H_2O+ - - - -	0·60
H_2O- - - - -	0·05
	100·53
Density - - - -	3·343

The following composition is to be deduced from these values:

$NaAl(SiO_3)_2$	74·35
$NaFe(SiO_3)_2$	3·95
$NaCr(SiO_3)_2$	11·26
$MgAl_2(SiO_3)_4$	1·50
$CaSiO_3$	1·55
$MgSiO_3$	6·70
$FeSiO_2$	0·11
	99·42

The morphological characters, characteristic pleochroism, chemical composition and other optical properties of this mineral agree closely with those of tawmawite, and Lacroix has suggested that it seems prudent to abandon the term "tawmawite," and to name the mineral in question *chromojadeite.*

In the jadeitite an amphibole occurs in large laminae, of a greenish-brown to a blackish-green colour, reminding one of diallage. This is the *szechenyite* described by Krenner. Another amphibole is greenish, acicular, and similar to actinolite, but it is chemically like the preceding one. The following table gives Krenner's analysis (1), and that of the acicular variety (2) by J. Orcel.

	(1)	(2)
SiO_2	55·02	58·65
Al_2O_3	4·53	5·98
Fe_2O_3	1·04	2·37
FeO	3·28	1·34
MgO	20·36	18·56
CaO	8·00	1·40
Na_2O	6·71	9·30
K_2O	1·52	1·10
H_2O	0·51	2·20
	100·97	100·90

It will be noticed that these amphiboles possess a special composition, and do not correspond either to glaucophane or to common hornblende, as has been generally believed.

The albitites are granulitic rocks composed almost exclusively of untwinned albite ; but, as in the case of the jadeitites, types containing amphibole and pyroxene also occur.

The chemical compositions of four different types (2-5) are

quoted from Lacroix's account together with the theoretical composition of albite (1):

	(1)	(2)	(3)	(4)	(5)
SiO_2	68·7	67·10	63·47	66·30	59·42
Al_2O_3	19·5	20·42	20·76	19·94	10·81
Fe_2O_3	—	0·23	1·27	0·19	1·28
FeO	—	—	—	0·43	2·58
MnO	—	—	—	0·07	0·17
MgO	—	—	1·11	0·22	10·69
CaO	—	—	1·16	0·72	4·30
Na_2O	11·8	8·93	11·98	11·25	8·01
K_2O	—	3·20	0·34	0·28	0·61
TiO_2	—	—	—	—	0·40
P_2O_5	—	—	—	—	—
H_2O+	—	—	0·36	0·42	1·37
H_2O-	—	—	—	0·21	0·13
	100·0	99·88	100·45	100·03	99·77
Density	—	—	—	2·671	2·91

1. Albite, theoretical composition.
2. Albitite, analyst, H. W. Foote.
3. Jadeitic-albitite, analyst, H. W. Foote.
4. Jadeitic-albitite, Tawmaw, analyst, M. Raoult.
5. Jadeitic and amphibolite-bearing albitite, Tawmaw, analyst, M. Raoult.

The amphibolites.—These rocks have proved very problematical as regards their origin, and they are not altogether happily named. The author has retained the name "amphibolites," which was applied to them by Lacroix, but they are not amphibolites in the commonly accepted sense, that is, regionally metamorphosed basic igneous rocks with a granulitic texture, as they are believed to consist of *primary* amphibole. On the other hand "hornblendite" would be equally inapplicable, on account of the unique composition of the amphibole of which they are composed. Further, they are of hybrid origin as explained in detail below.

Three varieties of these rocks may be recognised; one is grey and composed of large twisted crystals and aggregates of amphibole; the second type is coarser grained, it has a vaguely schistose appearance and contains a little jadeite in the typical specimens from the Kadon Mine. The third variety is the

coarsest grained of the three and consists of a grey-blue amphibole mixed with emerald-green chrome-jadeite.

These amphibolites contain nodules of chrome-jadeite, they are often rich in chromite and show evidence of intense mechanical deformation.

The following is the composition of these szechenyite-bearing amphibolites, which constitute a lithological type quite unknown elsewhere.

1. Amphibolite, Kadon Mine, analyst, Raoult.
2. Amphibolite, Tawmaw, analyst, Raoult.
3. Amphibolite bearing chrome-jadeite, Tawmaw, analyst, Raoult.

	(1)	(2)	(3)
SiO_2	56·18	55·82	57·52
Al_2O_3	7·37	2·56	9·57
Fe_2O_3	2·26	3·36	0·31
FeO	3·69	2·59	4·50
MnO	0·09	0·09	0·16
MgO	16·97	21·20	13·27
CaO	0·84	1·16	3·18
Na_2O	9·18	9·12	8·83
K_2O	0·72	0·53	0·51
TiO_2	tr.	—	0·10
H_2O+	2·41	3·21	1·71
H_2O-	0·28	0·30	0·23
Cr_2O_3	—	—	—
	99·99	99·94	99·89
Density	3·027	3·006	3·120–3·146

The so-called chloritic zone.—Bleeck described the peripherial zone as composed of chlorite (with chloritoid, actinolite and zoisite). The specimens, collected by the author from the Kadon Mine and described by Lacroix, have a different composition. One specimen is of a green colour, much crushed and folded, contains veinlets of calcite, and is composed of serpentinous minerals and broken needles of jadeite. The other is composed chiefly of fine needles of amphibole in a fine textured, irresolvable base.

The analyses below show marked differences between these rocks and those described by Bleeck, though they may occupy the same situation.

A. Serpentinised rock containing jadeite, Tawmaw.
B. Contact rock, Tawmaw.

	(A)	(B)
SiO_2	41·50	47·52
Al_2O_3	5·15	5·38
Fe_2O_3	2·76	3·20
FeO	2·19	1·99
MnO	0·10	0·10
MgO	27·39	24·95
CaO	3·66	0·70
Na_2O	3·59	5·76
K_2O	0·63	0·79
TiO_2	—	—
P_2O_5	—	—
H_2O+	8·89	6·86
H_2O-	1·15	2·43
Cr_2O_3	0·41	0·41
CO_2	2·82	—
	100·24	100·09

Origin of the jadeite-albite rocks.—Rosenbusch [1] noticed that jadeite may have been formed by the addition of one molecule of albite to one of nepheline. Such a composition is comparable with that of a leucocratic nepheline-syenite, almost exclusively sodic. The density of jadeite is much greater than that of albite, therefore high pressure must have played its part in its formation.

Pirrson, Iddings[2] and Grubenmann[3] considered jadeitite to be an orthoschist, the last named referring the rock to the deepest zone of dynamo-metamorphism, the Tiefeste Zone, the corresponding rock type from intermediate depths being nepheline-gneiss (Mesoalkaligneiss).

Noetling and Bleeck agree in considering the whole of the Tawmaw sodic rocks as forming a dyke of eruptive origin. Bleeck, however, considers that, from the genetic point of view, the jadeitite and albitite must be separated from the amphibolite, the first two having been intruded into the latter, which he believes to be genetically related to the peridotites. In support of this view he stresses the occurrence of xenoliths of the amphibolite in the jadeite-albite rocks, the enclosures being aligned parallel to the margins of the dyke, while a " ribboned

[1] Rosenbusch, H., *Elemente der Gesteinlehre*, 1910, p. 647.
[2] Pirrson, L. V. and Iddings, J. P., *The Bishop Collection*, vol. i, 1906, p. 162.
[3] Grubenmann, U., *Die Kristallinen Schiefer*, 1910, p. 228.

texture" is frequently here developed. Bleeck explains the presence of chromite in both the peridotites and the jadeite-albite rocks as due to their close magmatic relationship, the serpentinised peridotites and the gabbro (in the course of being transformed into crystalline schists) being products of differentiation from the same body of magma, and this gave rise, as an end member of extreme composition, to a nepheline-aplite. This nepheline-aplite, instead of appearing in its original form, has been changed after intrusion into jadeite-albite rock, the change being in the nature of an exomorphic transformation effected by granite magma intruded under high pressure following tectonic activity.

Professor Lacroix thinks that the jadeite, albite and amphibolite are linked together in a different way from that suggested by Bleeck. It is important to note that the composition of the amphibolite is unique : its low content of lime and alumina will not allow one to regard it as derived by regional metamorphism from the gabbro. Further, it is very rich in magnesia and, like the white rocks of the dyke, is characterised by a high content of soda and low content of potash. Thus, in some respects it appears to be linked with the albite-jadeite rocks, and in others, with the peridotites.

Lacroix does not think that all the Tawmaw rocks can have been produced by the normal differentiation of a nepheline-rich magma on the following grounds : all the known examples of such magmas are characterised by the absence of chromite and low content of magnesia in the leucocratic rocks formed from them, while the mesocratic and melanocratic members, such as theralites, are rich in lime and iron as well as in magnesia. This contrasts strongly with the amphibolites of Tawmaw, the analyses of which in fact do not correspond with any other known rock. On the other hand, the peridotites into which the Tawmaw dyke was intruded are destitute of alkalies, and practically without lime ; they consist essentially of magnesia and iron, and contain a little chromite. It is noteworthy that all the rocks of the dyke contain chromite, and Lacroix states that the green spots in the dyke rocks are indubitably due to chromite.

Lacroix claims that the dyke fissure was originally filled with

a highly aluminous and richly sodic hololeucrocratic magma, which stoped its walls, the amphibolite representing endomorphosed portions of these. The amphibolite, on this view, is certainly not crystalline schist which has been metamorphised by the magma, but represents peridotite that has contributed magnesium, iron and chromium, while the magma has contributed soda and silica. Further, it is evident that to provide the requisite silica to effect the transformation, a more highly silicated magma than the nepheline-bearing type postulated by Bleeck, must have been involved. It seems reasonable to suppose that this magma had the composition of granite-aplite.

Bleeck pointed out that there is a narrow zone of chlorite-schist, bearing chloritoid and chrome-epidote, between the peridotite and the dyke rocks. This he regarded as part of the metamorphic aureole of the dyke. Lacroix states that no such rocks were found among those which he examined, and finds it difficult to understand how a purely sodic magma could, by interaction with peridotite essentially free from lime, give rise to lime-rich minerals such as zoisite, tawmawite and others. This point is referred to again below.

Lacroix regards as important corroborative evidence the fact that certain glaucophane-schists associated, according to Bleeck, with the chlorite-schists, and derived from the gabbro, are chemically entirely dissimilar from the amphibolite of Tawmaw. This is brought out by the analysis recorded below, which should be compared with the analysis of the amphibolite on p. 71.

SiO_2	47·12
Al_2O_3	12·45
Fe_2O_3	7·14
FeO	9·72
MnO	0·21
MgO	6·36
CaO	6·92
Na_2O	3·19
K_2O	1·17
TiO_2	2·70
P_2O_5	0·09
H_2O+	2·69
H_2O-	0·22
	99·98

Glaucophane-schist with epidote, Burma (125–B), quoted from Lacroix, A. *op. cit.*

As noted above, Grubenmann regarded jadeitites as the end product of the conversion of nepheline-syenites, through nepheline-gneiss, into crystalline (jadeite-) schists. Lacroix points out, however, that he has described from Madagascar certain ortholeptynites (deep-seated types of Grubenmann) associated not with jadeitites, but with nepheline-gneisses; while at Tawmaw albitites and amphibolites, characteristic of Grubenmann's intermediate zone, are found side by side with jadeitite, in the same dyke.

It may be remarked that similar field relations have been described by A. L. Hall [1] from a South African locality, where granite-pegmatite traverses altered peridotites, highly magnesian like those of Tawmaw. The magma has here suffered extensive desilication, the pegmatites losing their quartz, but corundum, not jadeite, has been produced as a distinctive new mineral. Evidently the physical conditions and the actual composition of the magma involved were not identical with those at Tawmaw; but the example serves to prove that highly magnesian rocks are capable of causing desilication of acid magma with the complete disappearance of quartz and the development of undersaturated minerals.

Having discussed the views expressed by different petrologists on the origin of the jadeite-albite rocks of Burma, the author, who in the course of his official duties has studied the rocks in the field, is able to confirm the main conclusions arrived at, on theoretical grounds, by Professor Lacroix. There is no shadow of doubt that the jadeite-albite rocks are intrusive into the serpentinised peridotites of the district, either in the form of dykes, as has been commonly supposed, or more probably in the form of sills, as is evidenced by the numerous sections examined by the author.

With regard to their mode of origin, they are evidently products of interaction between a magma that was notably rich in soda, but deficient in lime, magnesia and iron, and the wall-rock, which was serpentinised peridotite. As a direct consequence of this reaction the rocks and minerals of the contact zone, which also occur as inclusions in the jadeite-albite complex, were formed. These comprise chlorite-schist, amphiboles,

[1] A. L. Hall, *Trans. Geol. Soc. South Africa*, vol. 25, 1922, p. 43.

chrome-epidote and chrome-garnet, the relationships of which have been explained in the account of the Tawmaw sheet. It may be remarked that both Bleeck and Lacroix were misled by the small number of specimens available, and these came from one locality (Tawmaw) only; the author has had the great advantage of examining very many outcrops of these rocks, and his main conclusions have been incorporated in the reports of the Director of the Geological Survey of India, as noted in the above account. It will be seen from the foregoing discussion that Lacroix found it difficult to account for the presence of the lime-bearing minerals occurring at the contact and as inclusions in the main intrusive mass. Consequently he was inclined to question the existence of "tawmawite" or chrome-epidote, as described by Bleeck. There is, however, no doubt that "tawmawite" does occur in the contact rocks at a number of different localities, usually associated with the chrome-garnet, uvarovite, particularly from Maw-sit-sit. This fact has not been previously recorded.

The explanation is undoubtedly to be found in the fact that not only dunites, which are of course lime-free, but also other types of peridotites, including diallage-bearing varieties, are present in the ultrabasic complex, and these are adequate to supply the lime necessary for the formation of these minerals.

The author believes that the immediate parent of the albite-jadeite rocks was a soda-granite-aplite produced as a normal product of differentiation from the granite magma represented in the district by the types enumerated above. The complete assemblage of igneous rocks in the district comprises peridotites of several types, gabbros of several kinds, locally represented by glaucophane-schist, by amphibolites, epidiorites, etc., and granites of several types, including pegmatites and aplites, the latter consisting of albite and quartz. The author agrees with Lacroix that the jadeite-albite rocks were derived from the magma represented by these aplites. The aplitic magma, a residuum from the granite magma, on coming into contact with the ultrabasic wall-rock suffered desilication, with the consequent elimination of the quartz and the conversion of much of the potential albite into jadeite. The silica released from the

magma was used up in converting the orthosilicates of the peridotites into metasilicates, within the contact zone, which, as noted above, is characterised by soda-rich, but lime-poor, amphibole. It is important to note that the desilication is only partial, as the rocks still contain large quantities of albite, with only *some* jadeite. The latter is sometimes closely associated with albite in albite-jadeite rock; but in other cases it forms lenses of nearly or quite pure jadeite-rock, embedded in equally pure albite rock. The amount of jadeite present appears to be directly proportional to the quantity of albite. The distribution of the two minerals suggests imperfect separation, and it may well be that, on account of the superior specific gravity of jadeite (3·33 as compared with 2·6 for albite), it tended to separate under gravity control. Segregation and sinking of the jadeite would be impeded, however, by the high viscosity of the desilicated magma.

It has to be understood that these reactions took place under almost unique conditions, presumably involving very high pressure, under which conditions nepheline proved unstable. It is well known that albite and nepheline are associated in a number of types of elaeolite-syenite, and in all proportions; but the jadeite-albite association is extremely rare. The nepheline is usually accounted for by desilication of the albite molecule: but as jadeite is intermediate between these two extremes of composition, it would be reasonable to suppose that a limited degree of desilication would result in the formation of the intermediate compound, jadeite. But that is not the case except in very rare instances, as at Tawmaw. Although he postulates high pressure as the controlling factor, the author would emphasize that this was operative *during*, and not after the consolidation of the rock; he is not at all in favour of the hypothesis, favoured by Bleeck and Rosenbusch, to the effect that the jadeite has been formed by the dynamo-metamorphic compression of one molecule of albite with one of nepheline to form two of jadeite. Lacroix also does not favour such an hypothesis.

JADEITE TRADE.

Every piece of jadeite found has to be valued and the owner has to pay a commission of 5 per cent. to the valuation committee in the jade mines. As a rule the valuations in the mines are very low. If the financier elects to keep the stone (which he generally does), he has to pay half of the value of the stone to the coolies or workmen after paying the *Mahumanta* tax of 10 per cent. to the Duwa in whose jurisdiction the stone is found, if it is valued at Rs. 100/- or more.

It is noteworthy that in sales and valuations prices are not mentioned openly, but are indicated by a conventional system of finger pressures under cover of a handkerchief.

The stone is then taken away to Mogaung, either by coolies or on mules, after paying the necessary local tolls. If a boulder is very heavy then the coolie transport from the mines to Nanyaseik is very costly. For instance, about fifty coolies or more have to be engaged to transport a boulder weighing about a ton ; these proceed by very short stages and in all it may cost about Rs. 1,000/-. Beyond Nanyaseik it may be taken by bullock carts to Mogaung, or it may be sent by river on bamboo rafts from Kamaing.

The stone can only be taken out of Mogaung after paying an *ad valorem* royalty of 33 per cent. to the Government Jade license.

Much dealing in jade goes on in the mines and at Mogaung amongst Burmese, Chinese and other traders ; but it is entirely speculation, because usually the stones are not cut until after the Government royalty has been paid on them, and therefore their real value is merely guess-work. I may quote here from a manuscript note by Major F. L. Roberts, formerly Deputy Commissioner, Myitkyina. " From the time jade is won in the Jade Mines area until it leaves Mogaung in the rough for cutting there is much that is underhand, tortuous and complicated, and much unprofitable antagonism. In my opinion the whole business requires cleansing, straightening and the light of the day thrown on it."

Shipping.—Boulders of jadeite are wrapped in gunny bags, tied with hemp rope and then shipped from Rangoon, in a

Chinese boat to Hong Kong, Canton, Shanghai, etc. A considerable quantity of stone is smuggled across the border, in addition to the small amount officially carried over by mules, which return from Burma to Yunnan and China with the advent of the rainy season.

Buyers of Jadeite.—No definite statistics regarding the purchasers of jadeite are available. However an aged, experienced dealer informed me that only about 25 per cent. of the jadeite is consumed in Burma. The remaining 75 per cent. is sent to China and Japan, and of this a small percentage eventually finds its way to America and Europe. The Chinese Government buy a considerable quantity of jadeite for making altars, sacred vessels, flower basins, etc. The Chinese believe that the wearing of jade prevents " evil eye," disease, or in other words acts as a charm. Jadeite jewellery finds great favour with the Chinese and Japanese ladies.

Centres of Jadeite trade.—A large number of the Chinese jade merchants make their purchases at Mogaung, but a fair number of Chinese merchants come up to the jade mines and are to be seen buying the mineral at Hpakan, Hwehka and other mining centres. Mandalay being the centre of cutting, commands the largest market for jade jewellery.

Varieties of Jadeite.—The local merchants recognise a number of varieties, depending upon their colour, translucency and texture.

(1) *Mya Yay* or *Yay Kyauk*, translucent and a uniform grass-green in colour. This is the most precious variety.

(2) *Shwelu.*—This is the light-green jadeite with bright-green spots and streaks. This is next to (1) in value. Both these varieties are used for expensive jewellery such as rings, necklaces, pendants, ear-rings, brooches, etc.

(3) *Lat Yay*, clouded jadeite, is used in making bracelets, buttons, hatpins, ornaments, drinking cups, etc.

(4) *Hmaw Sit Sit*, a dark-green variety, is rather soft and brittle, and is used in the manufacture of cheaper jewellery.

(5) *Konpi*, the red or brownish variety, is only found in boulders, embedded in red earth. This variety is not found at Tawmaw.

(6) *Kyauk-atha*, white translucent jadeite, is used for brace-

lets, stems of pipes, plates, spoons, flower-pots, cups, saucers, etc.

(7) *Pan-tha* (*Pan* in Burmese means flower, and *atha* means flesh, but it here denotes the translucent white jadeite). This variety is brilliant white in colour, and translucent, but opaque to a certain extent. This opacity is considered to be a defect and considerably reduces the price of the find. Like marble, it is used purely for decorative purposes, such as inlaying tables, chairs, boxes, and furniture generally.

(8) *Kyauk Amè*, the black variety. It is used for making buttons, bars for brooches, etc. This is the variety chloromelanite and is characterised by containing a large percentage of iron, replacing in part its aluminium. As the name implies, it is of dark-green colour often appearing quite black, except in thinnest splinters, when it is seen to be of a slightly translucent blackish-green colour.

Jade-cutting Industry.

The methods employed in the cutting of jadeite and described below are really Chinese, and artistic carving is still mostly done in China. Surface carving and bead-making can be done in Mandalay.

Abrasives.—Two kinds of abrasives are used in the cutting of jadeite. For big boulders coarse carborundum is employed, while the finer grade is used in disc-cutting described below. Crushed gem sand from Mogok is also employed in grinding and polishing.

About 20 years ago a basket of the gem sand from Mogok (sand weighing about 200 lb.) could be bought for a rupee (one shilling and six pence); but at present the price varies from Rs. 7/- to 15/- depending upon the usual question of supply and demand. Before the sand is crushed into grinding powder, the gems of better quality are picked out to be used as jewels in watches. Most are exported to Europe, but some are employed locally in the manufacture of cheap jewellery.

Local Preparation of Abrasives.—The pounding and pulverising of the sand is effected by a simple contrivance. A heavy weight is tied by means of a string strung to a bow fastened on to the ceiling of the house. Generally this task is entrusted to

girls, who are paid according to the weight of sand they crush. These wages vary in direct proportion to the degree of fineness required.

The powder thus prepared is used in cutting and grinding; but it is largely made into flat slabs by mixing it with a kind of gum imported from China. These abrasive slabs are mounted on flat wooden rectangular plates, there being 15 or 16 kinds of these tablets depending upon the grade of the powder used.

The first stage in the cutting of jadeite is the sawing of the boulders with big, heavy bamboo bows. The length of the saw is variable and is about two feet high at the centre. The cutting is done with steel wire; generally two of three wires are plied together. The boulder rests on a wooden frame and the saw is worked by two men sitting at either end. On one side there is a small basin containing coarse carborundum powder and water, and during cutting this moist paste is continuously poured on to the boulder by means of a long rod either by one of the workmen or by a small apprentice boy.

Disc-cutting.—Smaller pieces of jade are cut by means of a sharp-edged disc about 14 inches in diameter and made of bronze. This is fitted on to a wooden axle worked by means of a leather strap tied on to two wooden legs operated by the cutter. Below the disc is kept a basin containing fine carborundum and water which are constantly replenished on to the jadeite piece which is being cut. The disc rotates at a high speed and its sharp edge armed with carborundum powder effects the cutting. The disc is re-sharpened by means of a small brick made of gem sand. Sometimes before a boulder of jade is sold, if it is promising, certain portions are polished to expose clearly to view the more valuable parts of the stone. Generally a small rectangular strip is ground and polished. This grinding is done by means of an emery disc, and then the exposed portions are polished with fine emery discs. The machinery employed in this case is the same as is used for disc-cutting, but the cutting disc is replaced by thick emery discs.

Shaping and Polishing.—The third stage consists in mounting the small pieces of jade on to bamboo sticks by means of sealing wax. By skilful grinding on the abrasive tablets of different grades the desired shape is imparted to rough pieces.

In this way buttons, bars for brooches, small pieces for making bracelets, and beads for necklaces are made. The selection of colour and matching of beads is entrusted to girls. The cut articles are polished on slabs of very fine-textured stone, brass, leather, etc.

Final Polishing.—The final polish to the jadeite jewellery is given by rubbing the articles on a dry bamboo with water. Finally the finished article is boiled for about fifteen minutes in a solution made up as follows :

Soda (Sapyagyan) - -	1 part
Lime - - - -	1 part
Water - - - -	10 parts

The above solution is boiled for fifteen minutes and then cooled and decanted. When the stone has undergone this treatment, it is cleaned with cloth and is ready for sale.

Boring of holes.—The boring of holes in necklace beads, buttons, cuff-links, etc., is a speciality and is generally done by skilled artisans. The bead or any article in which a hole is to be bored is fixed in a heavy wooden stage or on to a block of wood by means of sealing wax and the hole is bored by means of an Archimedean drill, the steel needle of which is tipped with a high class Brazilian diamond point. The drill is worked by means of a leather bow. On a small scale a sharp-pointed steel rod and carborundum powder serve the above purpose.

Making of Bangles.—The making of Jade bangles, like carving, is a speciality which involves considerable skill and risk and it is mostly done in China. However, a little is done in Mandalay as well.

The making of a jade bangle simply consists in first scooping out a cylinder of jade. This is done by means of a steel cylinder and carborundum. The same process is repeated so that a small hollow cylinder, which represents a crude bangle, is obtained. Then the edges are ground and the bangle is polished. This is a risky operation and a bangle may give way in the final stages on account of an undetected flaw in the stone.

Carving.—The utmost care has to be exercised in carving jade. The Chinese workmen, having determined from the natural shape of the block, and from its visible and probable flaws, into what object he will carve it, fixes it on a lathe and

gives it the general outline. The carving machine is a kind of lathe almost identical with the one used for disc-cutting. In this case, however, the small steel discs vary from the size of a rupee to that of a pice. Various types of discs are employed for coarse and fine carving, using very fine carborundum powder for this purpose. Work is started with the biggest disc and the artisan gradually changes on to the finer ones. The interior is then hollowed out first by drilling, with diamond-pointed needles, innumerable little holes all over the surface which is to be broken away. When this is completely honeycombed the partitions are broken down by tapping sharply with a hammer. Too hard a tap may shatter the half-finished object along some hidden flaw. The final polish to the carved article is given by a leather disc. This work, even in Mandalay, is almost entirely done by skilled Chinamen whose wages vary from Rs. 3½/- to Rs. 10/- depending on the amount of work done.

It is recognised that the harder the stone the more difficult the cutting, and the more brilliant the polish it is capable of acquiring. So great is the difficulty of carving jade that an elaborate piece may represent a lifetime's labour. In Kien-lung's ateliers in the Summer Palace at Peking the workmen succeeded one another without interruption day and night. Even then many years were occupied in completing a single piece.

Places where cutting is done in Burma.—The bulk of the cutting is done in Mandalay, but some is done in Mogaung and a little, almost negligible amount, in the jade mines, *e.g.* at Hpakan, Hwehka, etc.

Place where cutting and carving is done in China.—It appears that jade cutting and carving is a very extensive industry in China, the most important centres being Canton, Shanghai and Peking, though some cutting is done in Hong Kong also. A big cutting industry is centred at Teng Yueh in Yunnan ; so much so that every street in Teng Yueh has its lapidary's shop and lathe.

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CHAPTER IV

AMBER.

BURMESE amber, or *burmite*, as it is sometimes called, has been known to the Chinese from a very early date, most probably from the beginning of the Christian era. The amber mines, whence almost the whole of the Hukawng Valley amber is derived, occur near Maingkwan in the unadministered territory and about three miles south-west of the village of Shingban (26° 17′, 96° 35′). Mogaung in the Myitkyina district is the nearest railway station, which is 25 miles from Kamaing, whence the mines are about five marches distant. These mines were first visited by Hannay in 1836 and by Griffith in 1837. Noetling was the first geologist to visit them, in 1892, but he erroneously ascribed a Miocene age to the amber-bearing deposits. Murray Stuart visited them in 1922, and reported them to be of Eocene age on account of the occurrence in them of *Nummulites biarritzensis*. This age has been confirmed by the work of F. A. Bather, and especially of T. D. A. Cockerall, on the study of the insects found in amber. The author visited the mines in 1930, and a resumé of his conclusions is given in the General Report for the year 1930.[1]

1. Geology of the Amber Deposits.

The amber occurs in the lower Tertiaries (Eocene), which consist of very finely bedded dark-blue shales and sandstones, the former being generally predominant, while in some places the two are alternately interbedded with a few layers of limestone and conglomerate. Sometimes the sandstones of various shades and colours, light-blue, pink, greyish, 'salt-and-pepper' are almost laminated, and in places contain shaly concretions

[1] *Rec. Geol. Surv. Ind.*, vol. lxiv, 1931, pp. 33-34 and pp. 77-79.

varying in diameter from one to a few inches. Generally the sandstones and shales bear carbonaceous impressions and sometimes very thin coal seams, in which amber in the form of concretions is embedded. On account of the soft nature of the shales and sandstones few good exposures are seen on the surface, which might have led Hannay and Noetling to conclude that the country rock of the amber mines consisted of clay. But the pits, cuttings and sections along the stream courses give a good idea of the true nature of the geology and structure of the country. The rocks have been thrown into tightly compressed anticlinal and synclinal folds.

A good section of the lower Tertiaries is also to be observed in the Namje *hka en route* to Namsapmaw from Lalawng. The author obtained specimens *in situ* of limestone interbedded with sandstones and shales. The former, as observed by Murray Stuart, also contained *Nummulites biarritzensis*, which is a characteristic fossil of the uppermost beds of the lower Kirthar Series.

2. Amber Workings.

The following amber workings occur about three miles southwest of the village of Shingban :

1. **Nangtoimaw.**—This is apparently the locality visited by Noetling and also by Hannay. These workings are first encountered just across the first small stream from Shingban *en route* to the Noijè Bum. The locality was deserted about four years ago, and the pits, now overgrown with dense jungle, number about 200.

2. **Pangmamaw.**—After passing the workings of Nangtoimaw, Pangmamaw is reached, where in April 1930 only two Shan huts were to be seen.

3. **Khanjamaw.**—About three miles and three furlongs southwest of Shingban lie the workings of Khanjamaw (26° 15′ 50″, 96° 33′ 37″), which constituted the biggest centre of amber mining at the time of the author's visit (see Plate IV, Fig. 1). About 48 huts, accommodating about 150 miners, were huddled together here, and were inhabited by Kachins, Shans and Shan-Chinese. The deepest pit was about 45 feet deep ; it was lined with thin bamboos supported by heavy wooden posts. Water

FIG. 1.—SHAN-CHINESE WORKING AN AMBER MINE, KHANJAMAW, HUKAWNG VALLEY.

Notice the lever arrangement for hauling up the débris

FIG. 2.—SHOWING THE LEVER ARRANGEMENT FOR HAULING UP THE DÉBRIS FROM AN AMBER WORKING, AND ALSO THE WATER-PUMPING ARRANGEMENT WITH A BAMBOO PIPE BY MAN SITTING IN THE

appeared at a depth of 41 feet and was being baled in kerosene tins. It took about three hours for the whole of the water to be baled out. The coal seams or "*Payin Kyaw*" were first observed at a depth of about 40 feet from the surface, and good amber generally occurs at that depth.

4. The workings of **Ningkundup** are about 200 yards west-north-west of Khanjamaw. Fifteen Shan-Chinese were digging six pits here in April 1930. The strata here consist of blue sandstones and dark-blue shales.

5. **Noijemaw or Wayutmaw.**—The workings of Noijemaw or Wayutmaw are situated west of the Noijè Bum, Δ 1554. At the time of the author's visit, 20 miners were re-digging old pits with the object of going deeper (see Plate V). The locality is next in importance to the Khanjamaw.

6. **Kanoitumaw.**—These workings are situated a little north-west of the Wayutmaw. Here the amber-bearing strata consist of bluish sandstones and finely-bedded shales which dip about 50° to the east, with some reddish overburden. Here work is generally carried on during the rains by means of water-channels (mayaws) to help sluicing.

7. **Chetauk.**—The workings of Chetauk occur about three and a half furlongs south-west of Khanjamaw. In April 1930 seven pits were being worked. In addition about 500–600 deserted pits are to be seen in the neighbourhood. The amber-bearing rocks here consist of sandstones and shales. The former are argillaceous and finely bedded, almost laminated, and dip at 40°, 20° north of east.

The workings of Samhkamaw, Mawchiyet and Ngalanmaw also occur in the neighbourhood of Khanjamaw. The last two are almost deserted now.

Ladummaw.—Besides the main workings described above there are the workings of Ladummaw (26° 11′ 19″, 96° 28′ 4″) and Lajamaw. The former is situated on the left bank of the stream called the Ladum *hka*, which joins the Nambyu *hka* opposite its confluence with the Tari *hka*. From its mouth the Ladum *hka* has a general north-westerly course, and light-coloured pebbly sandstones with bands of sandstone and fossil wood of upper Tertiary age are observed for a considerable distance. The workings of Ladummaw lie about five furlongs

south-south-east of Nweseng Bum, marked 2277 on the ½-inch map.

The rocks here consist of dark-blue shales and bluish and greenish sandstones which dip south-west. The amber occurs at a depth of approximately 24 to 27 feet. As is to be expected the depth of the pits is greater in the direction of the dip. The thickness of the amber-bearing stratum or *Patsai*, as it is locally called, varies from six inches to one foot. On the east a small watercourse marks the limit of the workings, and on the west rises a hill covered with a tall forest. The mining is usually carried on during the dry season in the usual way, and the present maximum depth of the pits here is 24 feet, when water appears. Here the pits, however, are not barricaded with bamboos, and the author was informed that the depth seldom exceeds 30 feet. The workings are also narrower here, about 3 feet square.

Lajamaw.—Another important amber-bearing locality is known as Lajamaw (26° 14′ 58″, 96° 28′), and the workings are situated seven furlongs south-east of Hill 1640, and the present pits are situated about three furlongs east of where the path leaves the Namgawn *hka*, and a small dry stream-course encircles the workings. Many pits, now partially filled up and overgrown with jungle, testify to the flourishing condition of the local industry in past times. The pits are here rather shallow and the depth rarely exceeds 20 feet.

At the top yellow weathered shales are seen, which are succeeded by blue shales, and the amber occurs in soft dark-blue laminated shales with extremely thin coal seams and unindentifiable plant impressions. According to the miners the *Patsai* here occurs at a depth of a foot from the surface.

Amber in the Kapdup Hka.—About three generations ago a block of amber was found in a fishing-basket in the Kapdup *hka*. It is reported that the Chinaman who was working for rubber in the Hukawng Valley prospected for amber for one season and collected five to six viss (one viss = roughly 3½ lb.) of amber.

The strata, as exposed along the Kapdup *hka* and some of its tributaries, the Hkawngchit and the Shayit *hka*, consist of Eocene shales, sandstones with interbedded conglomerates and

PLATE V.

FIG. 1.—KACHINS REDIGGING AT WAYUTMAW WITH THE OBJECT OF GOING DEEPER FOR AMBER.

FIG. 2.—DIGGING FOR AMBER AT WAYUTMAW, HUKAWNG

limestones. It resembles the succession of the amber mines west of Noijè Bum and the occurrence of amber hereabouts is possible. In fact, a locality on the right-hand bank of the Kapdup *hka*, where a little amber occurs, is about eleven furlongs east-north-east of the Hill "3301" marked on the Sheet 92 F/SW. The mineral occurs in small nodules in the vertical, firmly-bedded Eocene shales with fine seams of coal which have a north-west–south-east strike.

3. Mode of Occurrence of Amber.

Burmese amber occurs in pockets embedded in blue sandstones or dark-blue shales with fine coal seams locally called *Payin Kyaw*. The presence of the latter is a favourable sign for the occurrence of good amber. The mineral generally occurs in elliptical or oval pieces and occasionally in round blocks, but is never found in irregular or angular blocks.

Good amber generally occurs at a depth of 32–48 feet; at shallower depths than that, even if it occurs, it is reported to be of poor quality. Big blocks of amber are rarely found in these small pits; *Mayaws*, *i.e.* water channels, used to sluice away the overburden during the rains, generally expose them. Bigger pieces of amber are generally found in finely-laminated blue sandstones or dark-blue shales.

4. Methods of Mining.

The amber mines are really shallow wells about three feet six inches square, and with a maximum depth of about 45 feet. The number of coolies working a pit varies from two to four, but generally three men work together. One of them digs underground with a hoe (wooden crowbar tipped with iron), while the second one hauls up the débris in small baskets, either by means of a Madras lever or by a long bamboo with a bent hook at one end, and looks in it for amber, and the third miner dumps the spoil. If four of them work together, then two of them work underground. The deep pits, especially when they are largely in the soft shales and close to one another, are lined with thin bamboo barricades. In deep pits water appears at a depth of about 40 feet, and is baled out by hand methods; the water

level is of course higher in the low ground (see Plate IV, Fig. 2).

Mining is continued until, according to the miners, a layer of sand is reached, and they believe that there is no amber beneath it. The Kachins call this "layer of sand" *Khumtsai*, while the Shans term it only *Sai*. It would be interesting to put in a few borings to confirm or disprove this belief. However, they cannot empty out water easily from the deeper pits, and mining on that account has to be stopped. This is the case also when a hard stratum of sandstone, which the miners cannot break with their primitive tools, is encountered. The rate of progress in a pit is about one and a half to two feet a day.

Mining is carried on throughout the year; but for three months from the latter half of February the local people, when they have gathered their harvest, flock to the mines in great numbers. They generally commence work at about eight o'clock in the morning and continue till about four o'clock in the afternoon. During the rains work is carried on by *Mayaws*, or water channels, which the Kachins call *Hka Hka raw*.

The Kachins, Shans, Shan-Chinese and Chinamen with some Nagas comprise the labour force. They are listed above in numerical order.

The author "made various suggestions with a view to the improvement of the amber-mining industry.[1] These include the preparation of a large scale topographical map showing all the old workings, to serve as a basis for a geological map, the existence of which, it is not improbable, might lead to the discovery of new amber-bearing localities. He also recommends the introduction of mechanical pumping appliances and of explosives, and thinks that it would be better to follow the amber-bearing stratum underground than to sink many small pits down to it."

5. Physical Properties.

Burmite is distinguished from many other amber-like resins by its superior hardness and greater toughness, which render it suitable for carving and turning. It varies in colour from pale-yellow to dull-brown. Fourteen varieties of amber are recog-

[1] *Rec. Geol. Surv. Ind.*, vol. lxv, 1931, p. 34.

nised locally, depending mostly on colour and shade of the mineral. For instance, amber of the colour of flame, honey, *sessamum*, horse-hoof, light-red, all bear separate names. In dark or black shades four varieties occur. Burmese amber, very like the Sicilian variety, *simetite*, possesses a strong fluorescence, particularly in ultra-violet light; but even in daylight a strong bluish tinge appears when viewed at under a certain angle, and sometimes it is so strong that fine yellow specimens appear to be of an ugly greenish colour. The cloudy variety so common in the Baltic does not occur in Burma. Its hardness varies from 2·5–3 and specific gravity from 1·034 to 1·095. By friction it becomes electrified and retains its electricity for some time.

A great percentage of the pieces found are opaque and discoloured. Many of the fragments obtained have their cracks filled with calcite, which renders the mineral of little economic value. In the specimen examined by Brewster he found these veins of calcite, which intersect each other, sometimes as thin as a sheet of paper, and in others about the twentieth of an inch thick.

6. Chemical Composition.

Noetling's specimens were examined by Helm, who found that the products of distillation included formic acid and pyrogallol in place of succinic acid. It was this fact that led to the mineral being given the name of burmite. On the other hand Meyer states, on the authority of Dr. Oster, that a specimen of Burmese amber yielded two per cent. of succinic acid, while Baltic amber contains twice to four times that amount. Its ultimate composition has been determined to be as follows:

Carbon - - -	80·05	per cent.
Hydrogen - -	11·50	,,
Oxygen - - -	8·43	,,
Sulphur - - -	0·02	,,
Total - -	100·00	,,

7. Amber Cutting.

Burmite is harder and denser than the Prussian amber, is easily cut and takes an excellent polish. The appliances for the cutting of amber are simple. They comprise a saw, a Kachin *dah* (a large knife), a file and sandpaper. First of all crude amber is cut into small pieces of desired size with a saw, made by fixing a piece of kerosene tin into a bamboo handle and cutting teeth in it with a *dah*. Then the rough pieces are made into the required shape with a knife, after which the final shape is produced with a small flat file. The polish is first given by rubbing with coarse glass-paper. Subsequently a leaf of a tree with a prickly back surface is used to give it a further polish. In its absence finer glass-paper is used. The method of making beads for rosaries for the Hpongyis and necklaces is different. Amber is also cut into necklaces, ear-rings, bars for brooches, buttons, cuff-links and other trinkets for personal ornament. These are mostly made in Mandalay and Mogaung. However, these articles represent just a small fraction of the amount consumed in the Kachin Hills, Hukaw̃ng Valley, Naga and Chin Hills. The making of *nadaungs* (ear-cylinders), for which most of the amber is used, is mostly done in Maingkwan.

8. Amber Trade.

Meyer has discussed the question whether Burmese amber was exported to the West in ancient times, basing his conjecture on allusions to Indian amber by classical writers. He thinks that it is very probable that amber was among the commodities known to have been brought by Phoenician traders from the East.

The amber at present is cut mostly into Kachin and Shan ear-rings and taken over to Assam where they are sold to the Nagas. The smaller bits of amber are sold to Shan-Chinese who take them over to Kamaing and sell to Chinamen. If a big block of amber cannot be sold at the mines it is taken to Kamaing, Mogaung or Mandalay, whence it may pass to China.

The buyers of amber are Shans, Kachins, Shan-Chinese, Nagas, Lushais and certain tribes from Assam. Of these, the

Nagas purchase most. The amber mines: Maingkwan, Kamaing, Mogaung, Mandalay and the Naga country in Assam are the important centres of the amber trade. A little amber naturally finds its way into European and American markets.

9. Other Localities.

Shwebo District.—Amber is known to occur farther south in the Tertiary strata, especially in the oilfields. Noetling reported his discovery of small pieces of fossil resin at Mantha (22° 54′, 96° 1′).

The amber is alleged to have been found in a bed of clay underlying a coal seam of Miocene age. The amber, which appeared similar to burmite, although perhaps a little darker, was difficult to extract on account of its brittleness, and the clay in which it was embedded was very hard.

Pakokku District.—Grimes, while working in 1898 in the Yenangyat oilfield, was shown by a Burman small pieces of amber said to have been derived from a stream about three miles north of Seikkwa (21° 8′, 94° 51′). The beds in which the amber was said to occur consisted of thin bands of yellow sandstone of Miocene age interbedded with the shales. They were full of fragments of partially fossilised wood, some partially converted into coal, already replaced by oxide of iron.

Piddington described some amber specimens under the name of hircine, also from the Yenangyat oilfield. These were stated to have been obtained from the petroleum wells at a depth varying from 100 to 200 feet below the surface. The amber was dark-brown, deepening in colour towards the centre. It was very tough and suitable for carving. It was stated at the time that a lump, 5 viss (a viss = roughly $3\frac{1}{2}$ lb.) in weight had been found in the same locality only a few years previously.

Thayetmyo District.—E. L. G. Clegg discovered brown amber in the Sibon *chaung*, one mile north-west of Mibauk (19° 27′, 94° 53′). The amber occurs in lignite in stringers of one inch in thickness, but the quality of the amber found on the surface is too poor to be of any commercial value.

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CHAPTER V

IRON-ORE DEPOSITS.

DEPOSITS of iron ore occur widely scattered in Burma, and some of them were worked during the time of the Burmese kings. According to Bell " The soldiers who followed the fortunes of King Anawrata and his successors had been armed with bows and arrows, swords and spears, home-made products forged from the iron smelted at Popa."

At the time of the visit of the traveller Ralph Fitch, about the end of the sixteenth century, he found every indication to show that the blacksmith's trade was in a flourishing state. About the year 1612 A.D. the King of Ava made some of the Portuguese people, who had settled down at Syriam and who were conversant with the art of smelting, work the iron ores in his territory. When smelting operations were regularly carried on under the guidance of the Portuguese the raw iron ore became a monopoly of the king, at whose orders alone could smelting be done. " The present Shwebo district was the chief centre of these operations. Iron was also obtained from the Magwe sub-division of the Thayetmyo district, from the Yamethin district and from the Pagan sub-division of the Myingyan district, chiefly on the west and south of Mount Popa ; this last is said to have been highly prized for its quality." Recently, however, both exploration and exploitation of the iron-ore deposits of the Northern Shan States have received considerable impetus, as they are required by the Burma Corporation Ltd. for use in their blast furnaces in the reduction of sulphidic ores of lead, copper, zinc, etc. The output of the iron ores, mostly from the Northern Shan States, for the period 1926–1930, is shown in the Table on p. 5.

NORTHERN SHAN STATES.

The Twinnge Deposits.

In the neighbourhood of Twinnge (21° 57′, 96° 25′) iron ores were worked probably in the times of the later Burmese kings. P. N. Datta, in a note published in 1900, was the first geologist to draw attention to them. Later on these deposits were studied in detail by J. Coggin Brown, who found that the ore occurs in rounded grains, pebbles and masses, sometimes several feet in diameter, forming a layer near the base of the mantle of red clay which overlies the dolomitic limestone of the Shan Plateau. The thickness of the ore-bed is about 3 feet, and the quantity originally available was estimated at approximately 275,000 tons.

It is concluded that the ore is of a residual nature and represents the ferruginous content originally present in the limestone, which has been removed by denudation since the plateau emerged permanently from the sea towards the close of the Mesozoic era.

The Manmaklang Deposit.

The iron-ore deposit of Manmaklang lies two miles east of Manpwe and two and a half miles from a siding on the main railway line in lat. 22° 50′ N., long. 97° 40′ E., at the foot of a limestone range which trends in a north-east–south-westerly direction. E. L. G. Clegg reported on the deposit in 1922. The country rock is limestone and the iron ore is exposed in tunnels and shafts, not as separate boulders, but rather as a mass of fragments separated by small amounts of clay and by open crevices. Loveman considers that the ore-deposit is a residual deposit, but J. Coggin Brown regards it as a replacement deposit formed by the action of iron-bearing waters of meteoric origin working downwards through the Plateau Limestone, which is exceedingly brecciated and soft hereabouts. The deposit was originally opened up by two drives, but it has now been developed into a large open quarry. The deposit at the surface is at least 200 feet long and 150 feet broad, but it is reported to have diminished to a thin 12 to 15-ft. band in the lower drive.

Mineralogical Composition of the Ore.—The ore appears to be mainly limonite of varying shades of yellow and brown. It is a light, rather porous material which contains, moreover, irregular bands and lumps of darker and harder mineral in which haematite seems to predominate. At the time of J. Coggin Brown's visit a large lenticular mass of marcasite was exposed prominently in the quarry face.

Mining.—The output in 1927 was about 1,300 to 1,500 tons per month, operations being carried on by Chinese labour in the open season only. According to Coggin Brown the larger and richer ore is hand-picked, the remainder is carted to a log-washing plant which separates dirt and an eighth-inch undersize.

Chemical Composition of the Ore.—The approximate composition of the Manmaklang deposit is tabulated below :

	Lump Ore.	Washed Ore.	⅛-inch Fines.
Iron - -	57 per cent.	54 per cent.	47 per cent.
Silica - -	2 ,,	3·5 ,,	6 ,,
Alumina -	Not stated.	2 ,,	Not stated.

The following is the approximate analysis of the ore as given by E. L. G. Clegg :

Iron - - -	52·00 per cent.
Silica - - -	1·5 ,,
Alumina - -	6·5 ,,
Lime - - -	1·8 ,,

The Residual Deposit of Manmaklang.

Close to the large quarry at Manmaklang there is an interesting deposit of residual origin consisting of the typical red earth of the plateau, crowded with small pellets of limonite and allied ores. Analyses of these pellets have shown them to be too aluminous in character to be used in the Burma Corporation's smelters.

The Man Pat Deposit.

The deposit of Man Pat, which lies some 6 or 7 miles to the south-east of the Manmaklang deposit, is a shallow residual one lying on the limestone, and quantities of a small-grained,

yellowish rubbly iron ore are carted to the Manmaklang washing plant. These make the combined output to be about 3,000 tons per month.

The Kunghka Deposit.

The deposit of Kunghka (23° 13′, 99° 19′) lies about 17 miles from Nam-tu, where the ore is transported by pack mules. E. L. G. Clegg was the first geologist to report on the deposit when mining was commenced in 1916, and up to April 1922 some 5,000 tons of the ore had been removed. But at the time of Coggin Brown's visit the output was about 7,000 tons, worked during the dry season only. The deposit is said to be situated on the Pangyun beds of Cambrian or Lower Ordovician age.

According to Coggin Brown the ore-body lies in a fault zone, and has been formed by the infiltration of iron-bearing solutions, resulting in the production of lenticles and veins of hard solid haematite in a soft matrix of red and yellow limonite. In the latter, platy crystals of specular iron ore and small nodules of barytes are of frequent occurrence. Occasionally much larger masses of barytes are found. Clegg, Loveland and Bloomfield believe that the iron of the Kunghka veins was probably derived from Plateau Limestone, which originally succeeded the Pangyun beds. According to E. L. G. Clegg the amount of iron in the hard and soft type of ore from this deposit is 61 and 47 per cent. respectively. The first figure represents the average of 2,500 tons of ore.

DEPOSITS OF THE WETWIN REGION.

A number of deposits of iron ore exist in the neighbourhood of Wetwin. The important ones, comprising the Pauktaw, Bawhlaing, and Naungthakaw deposits, were investigated by Coggin Brown, and the following notes are based on his observations :

The Pauktaw Deposit.

The Pauktaw quarry lies close to the Mandalay-Lashio railway line, some 4½ miles south-west of Wetwin station in the direction of Maymyo. It is a small excavation which was

worked in 1920 and 1921. Originally the iron ore cropped out at the top of a small hill and the workings gradually increased to a depth of 35–40 feet. In the old faces Coggin Brown found the lower layers of the red earth to contain shots of iron ore, while at the bottom was an ore-bed eight to ten feet thick—massive in parts, but more commonly with an " organ pipe " structure, and 1,700 tons of ore with an average iron content of 56–57 per cent. have been removed from this working. The analysis of pisolitic material from Pauktaw as given by the same author is tabulated below :

Fe	25·2	per cent.
Al_2O_3	19·0	,,
MgO	6·2	,,
MnO_2	11·2	,,
SiO_2	10·0	,,

The Bawhlaing Deposit.

The iron ore of Bawhlaing is a shallow deposit lying on the top of a limestone knoll, and occurs about two miles to the north-north-east of the Pauktaw deposit. According to Coggin Brown these workings commence as a long channel, some 200 feet across, which soon broadens out into a semi-circular excavation about 500 or 600 feet in diameter. Their total length including the channel is 1,200 to 1,300 feet. From this area approximately 200,000 tons of good massive ore have been taken, and there is still a reserve of roughly 40,000 tons left.

The following is the chemical composition of the Bawhlaing ore:

Fe	56·6	per cent.
Al_2O_3	3·7	,,
SiO_2	2·0	,,

The Naungthakaw Deposit.

The Naungthakaw property held by the Burma Corporation Ltd. lies about six miles to the north-west of Pauktaw in about lat. 22° 10′ N. and long. 96° 31′ E. The leased area has been divided into a number of sections lettered from A to O.

In section A the workable ores occur between elevations of 3,650 and 3,700 feet, varying from thin bands a few inches across in the north-west and south-east, to richer material

several feet thick, distributed in three well-defined patches in the middle of the southern half of the section. The average thickness of the overburden in the open cut is about eight feet, and this is underlain by some six feet of vesicular haematite, bearing indications of a little manganese ore.

Similarly, the remaining sections have been described by Coggin Brown, and the interested reader is referred to his paper in the *Records of the Geological Survey of India*, vol. lxi.

The following analyses indicate the percentage composition of the Naungthakaw ores:

	Washed ore as railed	Washed ore (fines)	Bright-red haematite from Section E.	
			I	II
Fe - - -	55·22–56·3	56·2	61·3	64·5
Al_2O_3 - -	3·3 – 3·5	0·3	trace	trace
SiO_2 - -	4·0 – 5·0	4·4	5·0	2·8

At the time of Coggin Brown's visit prospecting was being continued in the area, and over 400 pits had been sunk, many of which revealed a good thickness of ore, and as a result of the season's work, 200,000 tons of ore had been added to the reserves.

J. Coggin Brown has discussed the future prospects of obtaining additional supplies of iron ore in this region. The iron-ore deposits overlie the Plateau Limestone, which occupies a considerable area in the Shan Plateau and continues into the Karenni hills to the south and into China to the north. An average of four analyses of the dolomites as given by him is reproduced below:

CaO - - -	30·5	per cent.
MgO - - -	20·1	„
Insoluble - -	0·4	„

The specific gravities of the specimens varies from 2·75 to 2·83.

The limestone is covered for the greater part with a mantle of red earth with prevailing Indian-red or reddish-purple tints.

It attains depths varying from a few inches to 40 or 50 feet. It contains little or no sandy matter, is usually stiff and tenacious in character, and is sometimes full of pisolitic nodules of iron oxides and hydroxides, ranging in size from small shot upwards. La Touche is of the opinion that it has been formed by a process of lateritisation, the difference between the final products and ordinary laterite being perhaps due to the absence of siliceous matter from the limestone. Its origin can only be attributed to the accumulation of the insoluble matter in the limestone itself in the course of its degradation through weathering. J. Coggin Brown adds correctly that, if the red earth is a residual deposit, its iron content is also of the same origin. Originally, the oxides of iron and alumina were equally well distributed through the red earth, and their concentration into the irregular beds towards the base of the clay, as we find them to-day, is due to subsequent processes which have occurred in it since its formation. The author is of opinion that this concentration was perhaps brought about by the infiltration of meteoric waters, which leached the iron contents from the upper portions and deposited them at the bottom. This process, repeated for a long time, would account for the rich deposits in places where conditions for infiltration and the enrichment of iron contents were suitable. The topographical conditions should be also such that the iron deposits should not be removed by denudation. It is noteworthy that the ores from the lower portion of the plateau, and also the small pisolites, which occur in the higher portions of the red earth, are often highly aluminous. J. Coggin Brown, therefore, directs attention to the higher geographical horizons and well-drained gentle slopes for future exploration. He also adds that if prospecting operations are desired farther afield, the middle slopes of Hill 4,378, and of Taungma to the south and east of Wetwin, are suggested.

Iron-ore deposits of this type are notoriously irregular. Instances are known where a good ore sheet has thinned away to practically nothing, down towards an insignificant surface drainage channel, to appear again in quantity on the opposite slope.

SOUTHERN SHAN STATES.

La Touche observed large masses of brown haematite along the outcrop of the Naungkangyi shales on the eastern side of the Loi Twang range (21° 56′, 97° 43′) in the state of Kehsi Mansam. The same author adds that the shales themselves are not particularly ferruginous, and the occurrence is probably an instance of superficial lateritisation of the weathered portion of the beds.

Farther south the Palaeozoic limestones of the states of Poila, Pangtara and Mawson are generally covered with thick residual deposits of ferruginous clay, in which pisolites and small concretions of iron ore of a limonitic character are often present. Hard surface accumulations of iron ore of small magnitude occur, according to J. Coggin Brown, on the western slopes of the Mawson highlands, east of Te-thun (20° 58′ 15″, 96° 46′ 30″). Similarly large concretions of iron ore occur in the surface deposit at the foot of the Taunggyi ridge about miles " 95 " and " 96 " of the Kalaw-Taunggyi road.

MYITKYINA DISTRICT.

Htawgaw Sub-division.

A number of irregular blocks of schistose and massive haematite, ranging up to 2 feet in diameter, were found by the author, associated with boulders of porphyritic gneiss, for about 200 yards, about one furlong north-east of the Ngawmawalang Hka bridge on the Myitkyina–Htawgaw road.[1] They were seen extending into the side of the hill, and granite was seen to be intrusive into the shales which are dipping west. A little chalcedony was also observed.

Segregations of magnetite occur in the granite near its margin, about one mile north-west of the Lagwi Pass. The mineral was seen for about a height of 25 feet above the bed of the stream which crosses the Lagwi Pass road. The ore-body has a width of ten feet. Lower down its extent could not be ascertained.

Another locality, where similar segregations of magnetite occur, is about 300 yards north-west of where the main stream

[1] *Rec. Geol. Surv. Ind.*, vol. lxvi, 1932, p. 61.

bifurcates, one branch following the Lagwi Pass road. It occurs a little below the new road, and is actually exposed on the old path. Laterite blocks, probably as a result of decomposition of magnetite, are to be observed close by.

Kamaing Sub-division.

Three important and large outcrops of iron ores occur in the Kamaing sub-division,[1] besides the boulders of iron ores occurring in several other localities. The village of Lamong (25° 37′, 96° 15′) is situated on one of the outcrops in the north. Almost in the centre is situated the Hill 2609, on the map-sheet 92 C/6, which sends out spurs in all directions, and the maximum extension of the outcrop is just about a mile.

The second locality is situated about 1¾ miles south-south-east of Lamong village. The length of this outcrop is about 1½ miles, but the width, which is about one furlong, is very small, and the iron ores cap the south-south-easterly spur of Hill 2661, and the path leading to the confluence of the Uru and Saunghpe *hkas* passes over the spur. The highest point on the iron ores is marked " 2020 " on the one-inch map 92 C/2.

The third, which is observed on the Mamon-Haunghpa path, is the longest and the biggest outcrop. The iron ore sets in about a mile west of Nammaw village (25° 38′, 96° 15′), and continues intermittently for about 6 miles, to about a mile west of Kattang village (25° 31′, 96° 10′). At several places a hard crust of iron ore occurs, which is almost devoid of vegetation, except a little grass. This destitution of vegetation is believed to be the consequence of the formation of hard crust (lateritisation), as recorded by Dr. Fermor [2] also in his review of Prof. Lacroix's work on the laterites of French Guinea.

Near the Kyaungdawywa Pagoda, marked on the map 92 C/2, small hillocks of iron ore are to be seen, which must have been originally a continuous and level stretch of land, but now have been detached as a result of erosion. These hillocks are low and flat with steep sides, and in places jointing which simulates rough

[1] *Rec. Geol. Surv. Ind.*, vol. lxii, 1929, p. 54, and also vol. lxiii, 1930, pp. 36–37.

[2] Fermor, L. L., " The Work of Professor Lacroix on the Laterites of French Guinea," *Geol. Mag.*, decade vi, vol. ii, 1915, pp. 28, 77, 123.

bedding is to be seen. This hard crust, or 'cuirass' of Prof. Lacroix, continues for about half a mile to the north. It rings in places under the feet and constitutes the 'zone of concretion' of Lacroix. All these hard crusts were observed where the ground forms tabular plateaux with an almost level surface. A small outcrop of iron ores, possibly a continuation of the above, is seen near Namchep *hka*, where the Haunghpa–Mamon road crosses it.

In addition to the main occurrences, iron ores occur at the following localities also :

(*a*) On the left bank of the Sanhka *chaung*, where it is crossed by the Lonkin–Kansi road.

(*b*) Near Lama or Mabaw village (25° 42′ 22″, 96° 21′ 15″). Here it forms a hard crust with lateritic appearance, almost devoid of vegetation. A good section of the iron ores is seen in the Mabaw *hka*, near its confluence with the Uru river.

(*c*) Fantastic concretions of iron ore, mostly haematite, occur at Namshamo (25° 45′ 31″, 96° 22′ 28″) as strings and patches in the red earth, forming the soil and subsoil on serpentines. As a consequence of mining for jadeite they are to be seen in quantity on the old dumps.

(*d*) Boulders of iron ore, lateritic in appearance in places, are also associated with the red volcanic agglomerate, which extends from Sanhka (25° 41′ 8″, 96° 20′ 57″) to the Moschen *hka*. They are seen lying on the surface where, by capillarity and exposure to the sun, the red earth forming the matrix has been enriched in its iron content and consolidated. They were observed on the hill marked "1380" on the one-inch sheet 92 C/6, on the way to the Sanhka Hka *taungya*, and also near a small marsh west of the north Sanhka village *en route* to the Sisu Bum.

Mineralogy and Structures.—The ore in places occurs in the form of boulders dispersed in a rich red-coloured soil, while in others, as mentioned above, they form a hard crust on the surface. Sometimes both the boulders and the hard crust possess a marked lateritic appearance, but they are also massive and compact.

Minerologically limonite is present in almost all its forms—concretionary, massive and earthy (ochreous). Earthy, deep-

red, massive haematite showing mammillary and banded appearances is very common. In some of the specimens black specks of crystalline haematite with glistening metallic lustre are also visible. Goethite (?) with resinous or subadamantine lustre also seems to be present. As already remarked, fantastic concretionary, sometimes concentric, mammillary, banded and cellular structures, are very commonly observed.

It is noteworthy that boulders of siliceous breccia are frequently associated with the iron ores. The following is an analysis of the ore as given by A. W. G. Bleeck : [1]

Fe_2O_3	77·54	per cent.
SiO_2	1·63	,,
Al_2O_3	7·37	,,
H_2O	13·46	,,
P_2O_5	traces	
Total	100·00	,,

Origin.—Bleeck [2] considered these ores to be bog iron ores; but the author [3] believes that there is little doubt that they are of residual origin, formed by processes not unlike lateritisation. Ferruginous red soil forms a thick mantle everywhere on the peridotites and serpentines of the region, and the iron ores are simply a further concentration of the ferruginous contents, deposited by capillarity on the surface, as shown in the sequel. Every gradation between the ultrabasic rocks and iron ores is observed both in the field and in the laboratory. In thin sections of iron ores pseudomorphs of haematite are to be seen after olivine. In passing, it may be noted, as recorded by Sir T. H. Holland,[4] that peridotitic rocks also, as described above, are very rich in olivine, a mineral particularly prone to alteration to serpentine, etc. The iron which exists as protoxide in olivine is further oxidised and crystallised out along lines of fracture as magnetite or haematite, or in the hydrous form, limonite ; or, in other words, in this process of hydration the combined iron changes into hydrated sesquioxide, which by various stages of dehydration passes into the anhydrous form, haematite. The

[1] *Rec. Geol. Surv. Ind.*, vol. xxxvi, 1908, p. 263.
[2] *Rec. Geol. Surv. Ind.*, vol. xxxv, pp. 262–263.
[3] *Ibid.*, vol. lxii, 1929, p. 54.
[4] *Geol. Mag.*, decade iv, vol. vi, p. 542.

association of the iron ores with the peridotitic family of rocks is remarkable, because elsewhere they are conspicuous by their absence.

These occurrences as a rule occur at a level of over 2,000 feet above the sea, and generally occupy the tops of the plateaux carved into ridges by erosion in certain cases, and are hence comparable with the "High Level" ferruginous laterites of India, capping the basic rocks.

Putao Sub-division.

According to Murray Stuart [1] two huge isolated boulders of limonite occur in the upper reaches of the Hkalaw Wang, at the foot of the south-eastern slope of Kaungtang Hpong (situated at the head of the Daru Wang valley in the Nam Tamai-Nam Tisang divide). He believed that the iron ore was originally a replacement deposit filling a fracture, but the author is inclined to think that the origin of these blocks of limonite is perhaps the same as for those described above from the Kamaing sub-division.

MYINGYAN DISTRICT.

In the Myingyan district existed an indigenous and widespread, but now extinct iron industry. The author [2] observed numerous old iron-slag heaps and deserted furnaces on the western and north-western side of Mount Popa, where the rocks belong to the Irrawaddy Series, the famous storehouse of the ferruginous concretions which constituted the ore-material for the smelting industry. As recorded by Bell, legend connects the earliest history of the extinct smelting industry in Burma with Mount Popa.

The ore occurs as concretions in the Pegu and Irrawaddy Series. Both solid and hollow concretions occur, though the latter predominate. The former are mostly discoidal or ellipsoidal in form, but the latter present every variety of form and shape. They are cylindrical, spheroidal, discoidal, mammillary, and in fact possess all kinds of fantastic shapes. The

[1] *Rec. Geol. Surv. Ind.*, vol. iv, 1919, p. 253.

[2] *Journ. and Proc. Asiatic Soc. Beng.*, vol. 1926-1927.

concretions are composed of both amorphous and crystalline material.

Usually the concretions range from 1 to 3 inches in length, but bigger specimens are not uncommon. They sometimes attain to a length of 8 inches or even a foot. The maximum thickness of a single concretion seldom exceeds 3 inches, but the thickness of the band of concretions may be sometimes over 6 inches, though their disposition is extremely irregular. Thin bands of ferruginous quartz conglomerate are often associated with the concretions. Sometimes the number of quartz pebbles is but small, and the ferruginous material predominates ; in that case the conglomerates also, after removing most of the siliceous pebbles, were used as ore-material.

Mineralogy of the Concretions.—The chief mineral making up these concretions is haematite. Limonitic concretions are not rare. Both crystalline and massive forms of haematite are to be observed in the concretions. Apart from separate concretions of haematite and limonite, some specimens exhibit alternating bands of brownish-red haematite and yellowish-orange limonite. A little psilomelane is also associated with these concretions. The mode of origin of the latter was discussed by the author in the paper mentioned in the list of references appended at the end of the chapter.

The amount of iron was determined in two specimens, and the results are given below :

(1) One-third mile south of Phogan, - Fe=26·3 per cent.
(2) Near Thanbo village, - - - Fe=22·8 per cent.

Metallurgy.—The extent of this industry in the past can be judged by the widespread occurrence of the slag heaps that are found near the furnaces which were deserted about 48 years ago. In the neighbourhood of Mount Popa many abandoned furnaces are to be seen round several villages, *e.g.* Thanbo, Chhaungbya, Daungle, Sinluaing, Kywelu, etc. Theobald also noticed similar furnaces near the villages of Shanybander, Kiungalay and Yayben in the Province of Pegu (the then British Burma). Blandford, on his way to Mount Popa, records having seen iron furnaces near Kywelu, but mentions that they were not working at the time of his visit. At Thanbo

village, three miles south-west of Popa village, several deserted furnaces, more than a dozen in number, were seen by the author in 1925.

The furnaces and the methods of extracting iron were very simple. A furnace simply consisted of a sort of circular or oval pit, 3 to 4 feet in diameter, dug in compact earth in certain raised portions of the ground, *e.g.* the bank of a stream. The pit was connected with a circular hole above, a little more than a foot in diameter, through which the smelters added subsequent supplies of charcoal. They had no opening to provide blasts. They pounded the ore to small pieces, about the size of walnuts, and arranged alternate layers of charcoal and iron ore in the pit. After igniting the charcoal they closed the mouth of the pit by means of earth to keep back the heat, and continued adding charcoal from above till the temperature was high enough to melt the ore. The fuel used was charcoal made from the wood of the local trees.

LOWER CHINDWIN DISTRICT.

In the neighbourhood of the village of Natyin Daung in the Lower Chindwin district the Plateau Gravel is remarkably rich in round, hollow, ferruginous concretions, which appear to have been worked for iron by the local people not long ago. Slag-heaps also occur in the area, but the industry is extinct now.

PROME DISTRICT.

According to Theobald the upper portions of the Irrawaddian Series in Eastern Prome and adjoining districts of Burma is characterised by a profusion of concretionary nodules of brown haematite. These nodules were extensively smelted under the Burmese rule, but the industry, as in the Myingyan and other districts, has long been extinct.

TOUNGOO DISTRICT.

According to Theobald thick beds of lateritic iron ore occur along the base of the hills to the east of the Sittang river. Fryar, who described these deposits, stated that they are espe-

cially abundant between Yondaing (18° 0′, 96° 54′) and Thanzeik (18° 4′, 96° 53′).

THATON DISTRICT.

The area where the iron ore is known to occur in the Thaton district lies in the foothills of the Kyaikto ridge, east of the Sittang river, and is about 15 miles to the north-east of Mokpalin, a station on the Pegu-Moulmein branch of the Burma railways, 80 miles from Rangoon. Iron ore occurs in the form of segregations of magnetite in irregular lenticular bodies or lenses in a green metamorphosed rock which, according to Dr. L. L. Fermor,[1] was originally an augite-plagioclase rock, possibly a gabbro. He considers that the green metamorphosed rocks may now be classed as epidiorites.

Two occurrences of iron ore *in situ* are known, and they comprise rich segregations of magnetite about 30 feet in width with a general trend north 20° east–south 20° west. But so far, neither the true extent of the deposits nor their true direction is known. The amount of proved ore, therefore, is very small. Pits sunk in the soil cap and talus have in many cases yielded detrital fragments of rich ore. According to Sir Edwin Pascoe [2] the ore-bodies, which are of a lenticular nature, run approximately parallel to the granite contact in a roughly north–south direction. The whole area is capped, except in the stream courses, by a considerable overburden of soil, laterite and talus.

In addition to these iron-ore occurrences, large areas in the Thaton district are covered by laterite, and the rock is quarried in several places to be used as a road-metal and building-stone.

AMHERST DISTRICT.

Large areas of the Amherst district are covered by laterite. It is known to occur near the coast, and also occupies extensive areas in the valleys of the Salween and its tributaries. It is especially abundant on the Gyaing river. Haematite containing 85 per cent. of the metal is said to occur at several places on the Ataran river (16° 8′, 98° 2′) and its tributary, the Zimme (Zami). According to O'Riley, specular iron ore is said also to

[1] *Rec. Geol. Surv. Ind.*, vol. lxi, 1928, p. 63. [2] *Ibid.*, pp. 61–63.

occur on the island of Bilugyun in a hill composed of red iron clay.

TAVOY DISTRICT.

According to Helfer, Low and O'Riley, iron ore occurs in quantity near the town of Tavoy. There are said to be two beds of ore, one of which forms a hill, 2,000 feet in length, 400 feet broad and 40 feet in height. Ure analysed two specimens with the following results :

I.	Fe_2O_3 - - - -	86·5	equivalent to 60·55 metal.
	SiO_2 with traces of P_2O_5	3·5	
	H_2O - - - -	10·0	
		100·0	

The specific gravity of the specimen was 3·51.

II.	Fe_2O_3 - - -	86·0	equal to 60·2 metal.
	SiO_2 with traces of P_2O_5	0·9	
	H_2O - - - -	13·1	
		100·0	

The specific gravity was found to be 3·46.

Blundell records that, during one of the expeditions of the Burmese against Siam, smelters were sent down from Ava, and iron was manufactured on the spot into swords, knives, spears and other weapons of warfare.

MERGUI DISTRICT.

Large supplies of iron ore, as observed by the author, exist on Kalagyun Island, about six miles west of Mergui.[1] The ore mostly appears to be limonitic and lateritic in nature. The following is the chemical composition of a specimen taken from near Masanpa village :

SiO_2 - - - - -	9·97
Al_2O_3 - - - - -	2·20
Fe_2O_3 - - - - -	71·10
CaO - - - - -	1·90
MgO - - - - -	5·20
MnO - - - - -	trace
Loss on ignition - -	9·51
Total - - -	99·88

[1] *Journ. Burma Res. Soc.*, vol. xvii, 1927.

According to Helfer considerable quantities of iron ore occur on Mavin or Meaing Island (12° 22′, 98° 30′), ten miles to the south-west of Mergui. Ure pronounced the ore to be of good quality, with a specific gravity of 3·18 to 3·37. Similar iron ore occurs on Kala-khuing Island, near the mouth of the Lenya river, on two islands to the west of Malcolm Island and on White Pigeon Island to the north of the mouth of the Pakchan river (10° 0′, 98° 30′). The ore is reported to contain 40 to 60 per cent. of iron.

P. N. Bose notes that large quantities of lateritic iron ores occur in the valley of the Great Tenesserim river, but appear to be of inferior quality. An exceptionally pure sample from Therabwin (12° 18′, 99° 3′) contained 50·49 per cent. of iron.

Kyaukpyu, Arakan.

Walters [1] states that iron of excellent quality was formerly smelted from lateritic ores on the island of Ramri, and the metal was highly prized.

IRON PYRITES.[2]

Northern Shan States.

In the Northern Shan States, at Hungwe (23° 7′, 97° 11′) and near Man Pat (23° 12′, 97° 11′), several quartz veins carrying large quantities of iron pyrites occur. The locality is rather inaccessible, and hence the iron pyrites is considered to be of little value at present as a source of sulphuric acid.

Myitkyina District.

Iron pyrites containing a small percentage of copper pyrites occurs in veins associated with the galena deposits of the Shweli-'Nmaihka divide.[3] Although some of the veins are more than 10 feet wide the locality is so remote from civilisation and access to it so difficult that the locality has no commercial value at present.

[1] *Journ. Asiatic Soc. Beng.*, vol. ii, 1833, p. 264.

[2] Though iron pyrites, strictly speaking, is not exploited as an iron ore, however, for purposes of completion it is dealt with here.

[3] *Rec. Geol. Surv. Ind.*, vol. l, 1919, pp. 241-254.

Bassein District.

The locality, where a lode of iron pyrites is found associated with a vein of serpentine, is about four and a half miles southwest of Kwingyi, and is locally known as Dok-hta *Chaung* (Dog-hta in Burmese = vitriol, *Chaung* = stream). The serpentine is intrusive into the Negrais shales and sandstones, which are very much altered and highly indurated at the contact. The pyrites lode has an average thickness of about 6 feet and runs roughly in a north–south direction, but more in a north-north-west–south-south-east direction. The lode crops out at four places in a distance of about a quarter of a mile in a stream, which is a tributary of the Kanazo *Chaung*, and finally disappears beneath the Negrais rocks in the hills. At one place, at the time of the author's visit,[1] the known width of the lode was 40 feet, and it is expected that on further cutting the width may become greater. Overlying the lode is the red ferruginous cap or gossan, which is more clayey in nature. Intervening between the gossan and the pyrites lode brownish-black iron ore, probably haematite mixed with a little magnetite, the latter in octahedral crystals, was observed on the surface of the pyrites. There seems to be some copper pyrites associated with the ore, as pieces of malachite were also found there. Quartz is also present, sometimes in a well-crystallised condition. In places the lode is quite compact and massive, but in others it is of a conglomeratic nature, *i.e.* small pieces of pyrites cemented by the same matrix. The following is the chemical analysis of a sample of pyrites from this place:

Iron - - -	42·84	per cent.
Copper - - -	1·68	,,
Sulphur - - -	45·42	,,
Silica - - -	10·08	,,
Total - -	100·02	,,

Pyrites also occur in small isolated pieces in the Negrais rocks of the Arakan Yoma.

[1] *Journ. Burma Res. Soc.*, vol. xvii, 1927.

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CHAPTER VI

COAL AND LIGNITE DEPOSITS.

BURMA, unfortunately, is not rich in her resources of coal. Though this indispensable commodity is found in a number of places in the Province, yet it has seldom been successfully worked on a commercial scale, as either the outcrop of coal is very small, the locality is not easily accessible, or the quality is poor. Sometimes the coal measures are much faulted, contorted and crushed to powder. Burma has therefore to depend largely upon foreign imported coal. Excluding the Gondwana (Jurassic) coal of Loi-an and the Southern Shan States, the rest of the coal of Burma is of Tertiary age and is mainly lignitic. Although there are fairly ample reserves of this coal, it is found that, owing to the high percentage of volatile constituents and ash, its calorific value is low, and the coal is seldom suitable for fuel in the raw state for steam-raising in locomotives and ships. Another common defect of this coal is that it disintegrates into small fragments on exposure to air, giving an extremely high percentage of small coal and slack. The attempts therefore to exploit the Tertiary coal have hitherto not met with success. It is possible that the modern process of low-temperature distillation or of briquetting might enable some of the seams to be profitably worked. Below are described the deposits that occur in Burma. The following, however, are the important potential coal-producing areas of Burma :

Loi-an, etc., Southern Shan States—Jurassic.
Kalewa, Chindwin river—Lower Eocene.
Nam-ma, etc., Northern Shan States—Pleistocene.

Northern Shan States.

The coal-bearing Tertiary deposits of the Shan plateau have been described in Chapter XXV of the author's *Geology of*

Burma, and were shown to occupy a series of detached basins grouped around the base of the Loi Ling, the highest mountain in the Federated Shan States.

Lashio Coalfield.—The coalfield of Lashio occurs in the valley of the Namyau river. Noetling was the first to examine this area, and reported the occurrence of several outcrops, indicating the presence of a seam extending for about two miles, and which in one place was 30 feet in thickness. In 1904–5, the field was surveyed by La Touche and Simpson (29).[1] It occupies an area of 50 square miles; but the coal is exposed only along its southern edge, in the bed of the Namyau river and its tributaries which join it from the north. Coal was found in several places, in seams of thickness varying from a foot to 33 feet. It has not been possible to estimate the quantity of coal available on account of the lenticular character of the seams as revealed by excavations.

The coal is a brownish-black lignitic variety with a distinct woody texture, and on exposure to the air it quickly breaks up into small cuboidal fragments. It is entirely unsuitable as a locomotive fuel. The average composition, as shown by six analyses, is:

Carbon - - - - - - - -	31·08	per cent.
Volatile matter - - - - -	35·63	,, ,,
Water - - - - - - - -	20·65	,, ,,
Ash - - - - - - - -	12·64	,, ,,
	100·00	,, ,,

Man-Sang Coalfield.—This coalfield was surveyed by Simpson in 1905 (30), who found its area to be about 13½ square miles. Numerous outcrops were observed, but none of the seams exceeds 4 feet 6 inches in thickness. The coal is hard, shaly lignite, which disintegrates rapidly on exposure to the air. The average analysis of six samples is given below:

Carbon - - - -	36·32	per cent.
Volatile matter - - -	35·13	,, ,,
Water - - - -	14·23	,, ,,
Ash - - - - -	14·32	,, ,,
	100·00	,, ,,

[1] See list of references at end of chapter.

Man-se-lé Coalfield.—This field also was surveyed by Simpson (30), and its total area is about the same as that of the Mansang coalfield. Coal is found in six or seven places, but only one seam of workable coal, of small average thickness, is known to occur. An analysis of a sample from a seam 3 feet 2 inches thick yielded on analysis the following results:

Carbon	34·22	per cent.
Volatile matter	38·83	,, ,,
Water	14·73	,, ,,
Ash	12·22	,, ,,
	100·00	,, ,,

Namma Coalfield.—This coalfield occupies a total area of about 50 square miles and was first explored by Noetling in 1891 (23). A thorough examination of the field was carried out by Simpson (30), who proved that only two seams of economic importance occur. One of these, varying in thickness from 7 to 17 feet, was traced for a distance of about half a mile near Namma. The second, exposed near Monting, about 5 miles to the north-east of Namma, has a maximum thickness of 5 feet, but thins out rapidly and is of inferior quality. It was estimated that the Namma seams would yield about half a million tons of coal.

The coal is somewhat harder than that of the Lashio coalfield, but it is brittle when dry. The average composition of five samples is given below:

Carbon	38·81	per cent.
Volatile matter	36·90	,, ,,
Water	16·58	,, ,,
Ash	7·71	,, ,,
	100·00	,, ,,

Wetwin.—Three outcrops of coaly material, occurring 9 miles to the east of Wetwin (22° 5′ 30″, 96° 38′ 30″), were examined in 1914 by Coggin Brown. The definite age of the coal is not known, but it resembles the Tertiary coal of Lashio in composition.

It has a dull black colour and quickly crumbles into powder on exposure to the air. An average analysis of three samples shows the presence of:

Carbon - - - -	33·59	per cent.
Volatile matter - - -	38·38	,, ,,
Water - - - -	16·39	,, ,,
Ash - - - - -	11·64	,, ,,
	100·00	,, ,,

Southern Shan States.

Panlaung River.—The Panlaung coalfield was surveyed by Jones in 1887 (22), and was found to cover a total area of 150 to 200 square miles. Numerous groups of outcrops occur, but the seams are all thin and irregular, and none could be worked profitably. The beds are highly disturbed and the coal greatly crushed. The average analysis of eight samples is given below :

Carbon - - - -	65·81	per cent.
Volatile matter - - -	16·86	,, ,,
Water - - - -	4·82	,, ,,
Ash - - - - -	13·01	,, ,,
	100·50	,, ,,

Pwehla.—According to Jones, a seam of shaly coal, varying from 7 to 11 feet in thickness, occurs at Ngu or Ngotko-Yaygyi, 7 to 9 miles north-west of Pwehla (20° 51′, 96° 43′). The seam contains a large quantity of pyrites. Middlemiss described the seam as consisting of graphitic shale of no value as fuel.

Legaung.—A thin coal-seam was recorded by Jones as occurring at Legaung (20° 50′, 96° 33′) and at Titpalwigon, about one mile distant. The coal is very powdery and of poor quality. An average analysis of two samples is as follows :

Carbon - - - -	70·43	per cent.
Volatile matter - - -	12·50	,, ,,
Water - - - -	2·08	,, ,,
Ash - - - - -	14·99	,, ,,
	100·00	,, ,,

Thamakan.—Middlemiss has described a seam of coal at Po-pyu, 8 miles to the south-west by south of Thamakan (20° 42′, 96° 42′). In one place it is 3 feet thick and seems to be continuous along the strike. The coal appears to be of good quality, but friable.

Loi-an Coalfield.—The coal of Loi-an, near Kalaw, is of Jurassic age. The seams are irregular and dip mostly at high angles, while the beds are both contorted and faulted. Some of the seams are of good quality, but Dr. Cotter recommends further prospecting before attempts are made to exploit this coal.

Myitkyina District.

Three coal-seams, varying in thickness from 14 to 20 inches, were found by the author [1] about a furlong to the north-north-east of Makapin (25° 28′ 53″, 96° 13′ 4″), in the Myitkyina district. They are intercalated in almost vertical greyish carbonaceous shales, with a few layers of sandstone of Tertiary age, and have been traced for about 110 yards. The coal is lignitic ; it appears to contain pyrites, and is worthless from an economic point of view, owing to the thinness of the seams and their highly crushed condition.

Stumps of lignite have also been found in a number of localities around Hwehka (25° 29′ 3″, 96° 16′ 43″), as at Zibyugon (25° 28′ 45″, 96° 17′ 41″). The author [2] found coal in the Namjan *hka*, a little west of its confluence with the Hlainnawng *hka*, or about $2\frac{1}{5}$ miles north-north-west of Namyong (25° 40′ 3″, 96° 26′ 17″) in the Myitkyina district. There are five seams in all, but only one, the westernmost, is of good bituminous quality ; it is about a foot thick. The others are impure and sometimes merge into black carbonaceous shales. The coal is intercalated in very finely bedded, rather laminated, black carbonaceous shales and sandstones, which, close to the coal-seams, bear unidentifiable plant impressions. The beds dip to the west at about 75°. A sample from the best seam was found to be non-caking, and was analysed with the following results :

Moisture - - - -	7·31	per cent.
Volatile matter - - -	19·98	„ „
Fixed Carbon - - -	37·81	„ „
Ash - - - - -	34·90	„ „
	100·00	„ „

[1] *Rec. Geol. Surv. Ind.* vol. lxii. 1929, p. 34.

[2] *Rec. Geol. Surv. Ind.* vol. lxxii, 1930, p. 31.

In the same stream, near its junction with the Hpakan *hka*, three seams and small pockets of bright coal are interbedded with finely-bedded sandstones and black carbonaceous shales, dipping at 58° in a west-south-west direction.

A small lenticular seam of coal was found by the author [1] about $1\frac{3}{5}$ of a mile west-north-west of Tarongyang (25° 40′, 96° 45′) in the Kamaing subdivision of the Myitkyina district. It is exposed in a small watercourse, a tributary of the Wanga *hka*. The seam is surrounded by slightly arenaceous, blue, compact shales, which are highly jointed and contain leaf impressions. The rocks dip west-north-west at low angles. The subdivisional officer at Kamaing informed the author that coal also occurs near Sumdukawng, in the Lawa tract of his subdivision.

Hukawng Valley.

In the course of his work in the Hukawng valley, the author [2] found that coal occurs on the left bank of the Hkawngchit *hka* (26° 29′, 96° 59′) a little less than half a mile, about 5° west of south of the salt spring known as Hkawngchit Shayit. There are four coal-seams in all, varying in thickness from 10 inches to 3 feet 10 inches. In addition to these seams, coal also occurs in the neighbourhood in small lenses and in other thin seams, apparently of no economic value.

The coal appears to be crushed and friable, but this may be partly due to weathering. A picked sample was analysed in the Rangoon laboratory of the Geological Survey of India with the following results :

Fixed carbon - - -	46·18	per cent.
Volatile matter - - -	45·63	,, ,,
Moisture - - - -	1·49	,, ,,
Ash - - - - -	6·70	,, ,,
	100·00	,, ,,

It cakes strongly and has a specific gravity of 1·31. The coal-bearing rocks are of Tertiary age and consist of sandstones and shales, and just where the path leaves the Hkawngchit *hka* for

[1] *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, p. 42.

[2] *Rec. Geol. Surv. India*, vol. lxv, 1932, pp. 37-38.

the coal occurrence, blocks of limestone with *Nummulites* sp. were observed, thus proving its Eocene age.

Bhamo District.

The field of Mithwe (24° 5′, 96° 59′) was explored by Hayden in 1896. The coal occurs in three seams, the best of which is 2 feet 8 inches in thickness, but is shaly and of poor quality. The Tertiary strata with which this coal is interbedded are highly disturbed, crushed and intruded by igneous rock. An output of 25 tons was recorded for the year 1915.

Upper Chindwin District.

Kale River (23° 11′, 94° 20′).—Two specimens of coal alleged to have come from the Chindwin river were examined by Piddington (13), who described one of them as excellent steam coal which yielded the following results on analysis :

Carbon	67·85	per cent.
Volatile matter	26·50	,, ,,
Water	4·25	,, ,,
Ash	1·40	,, ,,
	100·00	,, ,,

The other was described as a jet coal, containing 23·40 per cent. of ash. A section on the Kale river, above its confluence with the Chindwin, was examined by Jones (22) in 1887, who found ten seams in an area of a square mile, all of which (except one with a thickness of 10 feet) were considered to be useless. A detailed survey by Noetling (23) showed that the field has a wide extent. The coal measures occur in the valleys of the Nantahin, Peluswa, Maku and Telong streams, extending to the north of the Kale river for a distance of 55 miles. In the Maku valley the aggregate thickness of coal available was estimated at 24 feet. The Nantahin–Peluswa tract was found to occupy an area of about 25 square miles, with a total thickness of 48 feet of coal. On the assumption that the coal could be worked to a depth of 1,000 feet from the outcrop, the total available yield has been estimated at 210 million tons. The field has not yet been developed, and the author learns that it has recently

been the subject of investigation by Dr. C. S. Fox, whose results are likely to be published soon. The average composition of the coal, as shown by thirteen samples, is recorded below:

Carbon	49·95	per cent.
Volatile matter	34·59	,, ,,
Water	10·14	,, ,,
Ash	5·30	,, ,,
	99·98	,, ,,

Two thin seams of shaly coal were found by B. B. Gupta in beds belonging to the Yaw Series in the Do *chaung*, about 3 miles west of Anauktaw (22° 50′, 94° 42′ 30″) in the Upper Chindwin district. The total thickness is 1½ feet, and the material is of no economic importance.

Katha District.

Several outcrops of coal were found by Noetling (23) in the neighbourhood of Pinlebu (24° 5′, 95° 24′). Most of the seams are too thin or too poor in quality to be of any economic value. The best seam, however, occurs near Yuyinbyet, south of Pinlebu, and is 4 feet in thickness.

Below is given an analysis of the coal:

Carbon	52·22	per cent.
Volatile matter	34·24	,, ,,
Water	6·60	,, ,,
Ash	7·04	,, ,,
	100·10	,, ,,

Shwebo District.

In 1855 Thomas Oldham visited the coalfield in the neighbourhood of Kabwet and described coal from three localities. L. D. Stamp and the author visited the region in 1924.

(1) **Thinbaung.**—Coal occurs at Thinbaung, where the seam is 4 feet in thickness, including 1 foot 3 inches of coal of poor quality.

(2) **Kyibin Stream.**—This locality is 5 miles west of Thingadaw, and the seam is 5 feet 6 inches in thickness, including shaly layers. The coal is flaky and woody in texture and contains much fossil resin.

(3) The third locality is 8 miles north-west of Thingadaw. Here the coal is about 4 feet in thickness and crops out for about 200 yards. It is hard and resembles jet, with much fossil resin.

The coal mines in the neighbourhood of Letkokpin (22° 48′, 95° 51′) and Kyetsubin, near Thinbaung (22° 47′, 95° 58′), were being worked in 1870 at the time of Anderson's visit. The seam worked was about 6 feet in thickness, but much of the coal was of poor quality. King,[1] who inspected the field in 1894, considered that the area with good coal is very restricted, and estimated the total output available at not more than 150,000 tons. The annual output of the mines at the time varied from 10,000 to 15,000 tons. The maximum output was 23,000 tons in 1896, but the mines, after considerable fluctuations in their fortunes, were ultimately closed in 1904. An interesting account of the various attempts that have been made to mine coal here in the past is contained in the "Report on the Settlement Operations in the Shwebo District, 1905–6."

A representative sample of coal from Letkokpin has the following composition :

Carbon - - - -	36·22	per cent.
Volatile matter - - -	37·68	,, ,,
Water - - - -	11·94	,, ,,
Ash - - - - -	14·16	,, ,,
	100·00	,, ,,

The fragmentary character of the coal is believed to be due to the local igneous activity, and basic igneous rocks are found in the neighbourhood of the occurrences of coal.

Lower Chindwin District.

B. B. Gupta observed outcrops of coal in the Yaw Series of Eocene age in two localities, one of them half a mile north-north-west of Goonyibin Sakan (22° 15′ 30″, 94° 36′) on the Goonyibin–Petpetin road ; the other, Kyochin *chaung*, about 2 furlongs north-east of Kyochin in the Lower Chindwin district. The occurrences, however, are considered of no economic value.

[1] *Rec. Geol. Surv. Ind.* vol. xxvii, 1895, p. 33.

Similarly farther north, at least four coal-seams were noticed by him, also in the Yaw Series. The topmost seam appeared to him to be the best; at least 3 feet of good coal could be obtained from it.[1]

Pakokku District.

Yaw River.—Several seams crop out in the Yaw river, and the field was surveyed by G. de P. Cotter (32) and Sethu Rama Rao. The coal seams occur in the lowest subdivision of the Pegu Series and are of Miocene age. The important occurrences are those of Letpanhla and Tazu. In the former, seams are exposed and have been examined for a distance of 1½ miles. The main seam is from 5 to 6 feet in thickness, including numerous partings of shale. In the Tazu area three fairly good seams are exposed in places, but the thickness varies considerably. The lowest seam has a thickness of 7 feet in one place, but again contains frequent partings of shale.

The highest seam increases in thickness from north to south, but does not contain more than 2 feet 7 inches of coal.

The coal contains a high percentage of moisture, and the following is the average composition of twenty-two samples:

Carbon - - - -	35·86	per cent.
Volatile matter - - -	34·15	,, ,,
Water - - - -	18·73	,, ,,
Ash - - - - -	11·28	,, ,,
	100·02	,, ,,

Minbu District.

Coal occurs near Kyaukset, 30 miles south-west of Minbu, and the thickness of the seam, which dips at 55°, is 4 feet 7 inches. Other thinner seams were described by K. A. K. Hallowes (35), but they are too poor to be of any value.

Meiktila District.

According to V. P. Sondhi,[2] several outcrops of coal occur between the Loi-an coalfield (20° 38′, 96° 37′) and Minapalaung

[1] *Rec. Geol. Surv. Ind.* vol. lxii, 1929, p. 34.
[2] *Rec. Geol. Surv. Ind.* vol. li, p. 34.

(20° 56′, 96° 30′). The latter place, though situated on the edge of the Southern Shan plateau, is actually within the Meiktila district. The occurrences are of little commercial value, as the coal itself is powdery, the seams dip at high angles, and the enclosing rocks are highly folded and faulted. The only locality that may be deserving of future attention occurs about one mile south of Legaung (20° 49′, 96° 32′ 3″), where three outcrops were found along the strike, all apparently belonging to the same seam.

Thayetmyo District.

Kyauk-Kala.—A bed of carbonaceous shale, containing a one-foot seam of hard bright coal, according to Theobald, occurs at Kyauk-Kala (19° 27′, 94° 44′). The seam has a very high dip and is probably worthless.

Thayetmyo.—An outcrop of coal occurs in the " Lime Hill," about 5 miles to the south of Thayetmyo. On examination by Thomas Oldham (17) the seam proved to be irregular in thickness. Subsequent exploration by Romanis (21) confirmed the opinion that the deposit is of little economic value. According to Piddington (14), the composition of the coal is as follows :

Carbon - - - -	64·10	per cent.
Volatile matter - - -	30·25	,, ,,
Water - - - -	2·50	,, ,,
Ash - - - - -	3·15	,, ,,
	100·00	,, ,,

Henzada District.

The following three occurrences of coal have been described by Romanis (20) and Stuart from the Henzada district.

Hlemauk.—An outcrop of coal occurs at Hlemauk (17° 50′, 95° 6′ 30″), but is only about 20 inches in thickness. The seam apparently extends for many miles to the south to Kyibin, but the quality is very poor, owing to a large percentage of iron pyrites.

Kywezin.—At Kywezin (17° 58′ 30″, 95° 9′) the seam is about 8 feet in thickness with a high easterly dip. The beds are

much faulted and contorted, and the coal is greatly crushed. The following is an average of three analyses :

Carbon - - - -	74·44	per cent.
Volatile matter - - -	17·59	,, ,,
Water - - - -	1·68	,, ,,
Ash - - - - -	6·29	,, ,,
	100·00	,, ,,

The above analysis shows a high percentage of fixed carbon, but practical tests gave disappointing results : for though the coal was found to be of excellent quality, yet a full pressure of steam could not be kept up in the boiler of an engine.

Posugyi.—A coal-seam occurs near Posugyi (18° 10′, 95° 7′ 30″), and the thickness at surface varies from 6 to 20 inches. The outcrop is close to a main fault and the beds are greatly contorted. The following is an analysis of a sample :

Carbon - - - -	69·65	per cent.
Volatile matter - - -	18·21	,, ,,
Water - - - -	6·36	,, ,,
Ash - - - - -	5·78	,, ,,
	100·00	,, ,,

Mergui District.

Several coalfields occur in the Mergui district, and have received attention both from geologists and prospectors at various times. The most recent note, published in 1930,[1] is by Dr. A. M. Heron.

Theindaw-Kawmapyin Coalfield.—Helfer was the first to mention this field in 1838 (6), and described the outcrop at Thahtyua, as showing one 6-ft. seam of coal of fair quality, though much contaminated with iron pyrites. In 1840 the Government commenced commercial prospecting operations, and a considerable quantity of coal was raised, but the loss of a vessel laden with it, through spontaneous combustion, led to the abandonment of work.

Thomas Oldham with Theobald visited the locality in 1885,

[1] *Mem. Geol. Surv. Ind.* vol. lv, 1930, pp. 23-31.

and also the occurrence to the north, on the Heinla *chaung*, in the Kawmapyin village. He reported seams of 6 feet to 17½ feet in thickness at three localities, and estimated the available coal at 19,360 tons per acre over an area of 4 square miles, *i.e.* 49,561,600 tons. In 1863, Harrison, and in 1871, Fryar, reported on the reopening of the Kyauk-Mithwe mine, but nothing was accomplished until 1892, when Hughes' prospecting party examined the Kyauk-Mithwe and Heinla occurrences and discovered a new outcrop on the Kaung-ye *chaung* of the new 1-inch survey map, also in Kamapyin village. In 1893, P. N. Bose (26) with P. N. Datta surveyed the field. Subsequently sporadic attempts at mining coal have also been made.

Theindaw.—The mines at Theindaw consisted of a number of adits sunk on the dip of the bed, where it outcrops in the Kyauk-Mithwe stream and for a few yards to the south. According to A. M. Heron, the whole of the outcrop appears to have been removed. The seam P. N. Bose reports as being 7 feet 2 inches thick, with three shale partings, or 6 feet 8 inches excluding these, and dips at 30° to the east-north-east. An analysis of the coal, made in 1842, yielded the following results:

Volatile matter (including water)	48·10 per cent.
Fixed carbon	45·40 „ „
Ash	6·50 „ „
	100·00 „ „

Its pyrites content was high, and it was the spontaneous combustion of a cargo of the coal that led to the abandonment of the mine. Taking the thickness over one quarter of a mile as 7 feet and allowing 25 cubic feet to the ton, Dr. Heron estimated the quantity available per 100 feet of sinking incline to be 36,960 tons. Bearing in mind the lenticular nature of the Tertiary deposits in this region and the irregular way in which the Great Tenasserim has eroded its banks, the same author was of opinion that conservative estimates must be adhered to. He adds that the Theindaw coal alone is not of sufficiently high quality to justify its exploitation, though it might be useful as an adjunct to the Kawmapyin scheme, if that matures.

Kawmapyin.—At Kawmapyin there are two outcrops, one on the Heinla *chaung* and the other three-quarters of a mile to the north, on the Htiphanko *chaung*, the " Kaung-ye " of the new map. In both cases the outcrop is exposed in the stream for a short distance, but is lost under the high banks as the stream and outcrop separate.

Heinla.—On the Heinla the coal-seams dip at 33° in a direction east 17° north beneath grey shales which become brown and carbonaceous near the seams. The outcrop was extensively prospected by Bose and proved by pits and bores for 100 yards along its length. Similar brown shales, according to him, occur lower down the Heinla *chaung*, about two miles along the strike to the south-east, but here contain no coal. His most northerly boring and pit gave a thickness of at least 13 feet of coal ; boring No. 1, 130 feet south of this along the strike, gave 28½ feet of coal ; the next and boring No. 3, 29 feet farther on, gave four seams of coal of 2½ feet, 4 feet, 3¾ feet and 6½ feet each, and in pit No. 4, 33 feet farther on, only 9 inches of coal were met with : it will be noticed that the seam decreases from 28½ feet to 18 feet in 84 feet longitudinally and then practically dies out in another 64 feet along the strike to the south. P. N. Bose (26), however, asserted that in the next three-quarters of a mile to the north, the average thickness of workable coal will be 15 feet, on the evidence of the Htiphanko section of 7½ feet of coal, three-quarters of a mile away. This assumption, in the opinion of A. M. Heron, is rash, especially in view of the fact that these coal beds are of an irregular nature, and nothing is known of what happens in this three-quarters of a mile.

An analysis of an average sample of the Heinla seam made in the Geological Survey of India Laboratory yielded the following results :

Moisture - - - -	16·40	per cent.
Volatile matter - - -	35·08	,, ,,
Fixed carbon - - -	44·24	,, ,,
Ash - - - - - -	4·28	,, ,,
	100·00	,, ,,

The ash percentage is low for Indian coals. Dr. A. M. Heron states that the higher amount of moisture in the sample is due

to its being taken actually from the bed of a stream and should become much less away from the surface. The coal cakes, though not strongly, and the ash is light buff. P. N. Bose states that it is a splendid steam coal, above the average of Indian coals. It contains very little pyrites, and in general is the best quality of the three localities, and also occurs in the thickest seam.

Htiphanko or Kaung-ye.—The coal-bearing beds dip here at 34° and the strike is a little to the east of north. Primrose of Hughes' prospecting party put down two pits 15 feet apart, and the section observed in one of them is as follows :

	Ft.	In.
Coal - - - -	0	10
Shale - - -	2	0
Coal - - - -	2	3
Shale - - -	3	0
Coal - - - -	4	6

The 10-inch band consists of only a few layers, and dies out within a few feet. Dr. Heron had some pits dug, and the sections then observed proved the very irregular thickness of this coal-seam. Analyses of three samples, A and B from the upper "2 ft. 3 ins." seam and C from the "4 ft. 6 ins." layer, were :

	A	B	C
Moisture - - - - -	15·20	10·80	11·34
Volatile matter - -	30·08	27·36	36·40
Fixed carbon - - -	30·86	42·52	43·27
Ash - - - - - -	23·86	19·32	8·99
	100·00	100·00	100·00

The coal is non-caking, and the lower seam (sample C) is obviously of better quality. It is hard, black, and breaks in all directions with a conchoidal fracture and shining surface.

Trials of this coal made on the Government steam launch, "Mergui," gave satisfactory results.

With regard to the question of transport, Dr. Heron considers river transport the best and cheapest. The same author points out that in further tests, drilling plant is necessary, capable of drilling a hole 300 feet deep and of passing through boulders and conglomerates; and it is desirable that it should give a

core. He recommends the Heinla outcrop for instituting further bulk tests, as it is the best coal of the thickest seam. In 1921 a company was registered to work the coalfields of the Tenasserim valley, under the name of the Tenasserim Coal Development Syndicate Ltd., and the Kawmapyin coalfield was developed energetically during 1923 both by boring, pit- and shaft-sinking. The net result of these operations was to prove the existence of a large tonnage of coal ; over 120 tons were brought down the river for testing. It is described as a saleable coal provided it can be supplied at a price comparing favourably with that of coal imported into Burma. In 1925, however, the activities of the Syndicate were suspended.

Lenya River Valley.—Another small occurrence of coal, of little economic importance, is known to occur at the confluence of the Pla-aw *chaung* and the Lenya river near its source. This deposit does not deserve the name of coal, but is more akin to lignite and oil shale.

Kyaukpyu District.

Coal seams of minor importance are found in Ramri and Cheduba Islands, but apparently the occurrences are of little economic value.

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CHAPTER VII

GOLD.

GOLD is widely distributed in several parts of Burma. It occurs associated with quartz veins; detrital gold occurs at a large number of the auriferous localities, but it is not certain whether they can be worked on a commercial scale.

Gold, *in Situ*.

Kyaukpazat, Wuntho, Katha District.—The only gold mines that have been worked in Burma occur at Kyaukpazat, 26 miles north of Wuntho and 11 miles from Nankan, the nearest railway station. The auriferous locality lies in the Tertiary consolidated and well-stratified tuffs and breccias of andesitic character; these have been intruded in places by quartz-diorite. Veins similar to those at Kyaukpazat occur at and near Legyin, 11 miles farther north and also in the vicinity of Banmauk.

The veins of this andesitic region are highly pyritic and low grade. The Kyaukpazat vein was proved to a depth of 420 feet, but the valuable portion seems to have been above the 310-feet level. The length of the ore-body was about 240 feet, and the vein was cut off to the south-west by an intrusive dyke. On the north-west it disappeared in the country-rock. Its thickness varied from two inches to ten feet, with an average of three feet six inches. Below the 310-feet level the quartz was associated with calcite. It was occasionally clean, but more often was well mineralised, carrying five per cent of chalcopyrite, pyrite, galena and franklinite. Altaite, the somewhat rare telluride of lead, was a very favourable indicator of gold.

Hkamti Long.—Gold is known to occur in the Hkamti Long at the head of the Irrawaddy valley. According to Maclaren (7) this country promises gold deposits rather in veins in the old

metamorphic rocks of the Miju and Zayul ranges than in the alluvium of rivers. The region being almost inaccessible, gold is not sought for.

Myitkyina District.—A gold-bearing locality in the crystalline schists, and locally known as Jamaw (25° 25′, 96° 18′) occurs near Woragahtaung. Numerous old pits, with a general depth of ten to twelve feet, were seen by the author[1] in this neighbourhood. The locality was abandoned about sixteen years ago.

Northern Shan States.—Auriferous quartz veins also occur in the gneissic range, lying south of the Shweli river in the Northern Shan States. These veins are thick and heavily mineralised, but of very low grade.

Southern Shan States.—For a considerable time, according to V. P. Sondhi, gold has been known to occur on the western slopes of the Mwe-daw hill-mass (20° 39′, 96° 28′ 30″) which lies to the west of Kalaw in the Southern Shan States. Old workings for gold are to be seen about half-way down the slope, in beds of marble and siliceous limestone, which are the result of alteration of almost pure limestones by igneous intrusions. Gold was also known to occur in the soil derived from these rocks, as is proved by numerous tailing dumps scattered over the area, where pan-washing was practised.

Just before the Great War systematic prospecting by modern methods was commenced, and the dilapidated remains of four horizontal tunnels still exist, but unfortunately no other records are available. At present a detailed investigation is being carried out by the Kafue Copper Development Co. Ltd., a company operating in South Africa. The old tunnels are being cleared ; and qualitative analyses of the samples taken are alleged to be giving encouraging results.

The origin of the gold is believed to be due to the dioritic and granitic intrusions into the Kalaw Coal Measure Series. As a result of these intrusions, the limestone beds have been either completely silicified or metamorphosed to marble, and large quantities of wollastonite have been formed. The richest gold values have been obtained in a highly crusted and recemented fault-rock accompanied by secondarily deposited silica, haema-

[1] *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, p. 60.

tite and malachite. Whether gold occurs in localised pockets or follows particular zones will be ascertained as a result of the prospecting proceeding at present.

Kyaukse District.—Middlemiss was informed that gold occurs *in situ* in quartz rock or gneiss in a hill about 3,000 feet high and about 10 miles to the north-east of Myogyi (21° 27′, 96° 24′) in the Baw State.

Detrital Gold.

Irrawaddy Valley.—The gravels of the Irrawaddy in the Myitkyina district have been known for a long time to be auriferous. Of course, sporadic washing has been done on its banks from a remote antiquity, but in October 1902 proper dredging operations were commenced by the Burma Gold Dredging Company, and for the greater part of the period 1909–1913 five dredges were at work. But the output fell short of expectations. The bed of the river dredged extended for some 120 miles from the confluence to the mouth of the Taiping, above Bhamo. Subsequently the area was restricted to Sinbu, where the river enters the first defile, and later on the lowest reaches of the 'Nmai *hka* and the Mali *hka* were also added to this area held under licence for dredging. The average annual output for the period 1914 to 1918 was 1,951 ounces. After 1918 there was no production of gold and the dredging operations were closed down altogether. The gold-bearing alluvium is coarse gravel with gold distributed fairly uniformly. The average yield of the gravel was about 3 grains per cubic yard. Small quantities of platinum and platinoid metals are associated with the gold.

Lower down the next auriferous occurrence is at Shwegu. In the Mozit *chaung*, near the mouth of the second defile, the fine gravels are slightly auriferous. Again, on the Irrawaddy, gold-bearing gravels occur near Prome and at Shwedaung, where spasmodic washing has been carried on a long time.

The sands of the Namsang *hka*,[1] a tributary of the Mogaung River, are reported to be rich in gold, and in the past there used to be considerable activity in places. To-day the villagers of Laban and Wakawng practise gold washing on a small scale.

The Chindwin River.—The gravels of the Chindwin are

[1] *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, p. 60.

also known to be auriferous in places, and the gold-washing industry is carried on sporadically by the local people in the Upper and Lower Chindwin districts. However, systematic prospecting has shown these to be too poor to be exploited on a commercial scale. In the Upper Chindwin district gold is said to be washed from the sands at Alon and Kani, and also from the Pettok *chaung* and the Shwegyin *chaung*, about three and a half miles south of Kyaukkedet (22° 57′, 94° 43′). Small amounts of gold are recovered in the Shwebo district from the Ngakuaing, Auk, Myindingaw and Teon *chaungs*. The gravels do not appear to be rich, as the workers only recover from four to five annas' worth a day each.

About ten to fifteen ounces of the noble metal are produced annually in the Lower Chindwin districts from tributaries of the Yama, Yewa and Hmyaing *chaungs*,[1] where washing is carried on for about two months during the rains, and the gold-washers are said to win about four annas (approximately equivalent to fourpence) worth of gold per day.

Lower Chindwin District.—Gold-washing is carried on on a small scale in the rivers of the Lower Chindwin district, flowing from the Paukin *chaung* and draining areas covered by the Irrawaddy Series. The industry dates back to the time of King Mindon, but villagers of Pauktaik (22° 10′, 94° 47′ 30″), Thaminthat (22° 15′, 94° 45′), Zibindwin (22° 16′ 30″, 94° 50′ 30″), Tuyeva (22° 24′, 94° 47′) and Nyaungbinle (22° 20′, 94° 39′) particularly practise this industry after the monsoon. The daily output for each party of two or three men varied at the time of B. B. Gupta's [2] visit from $\frac{1}{8}$th to $\frac{1}{4}$th *tola* by weight of gold (approximately $22\frac{1}{2}$ and 45 grains respectively).

All these occurrences are in the Irrawaddian sand-rock, where very fine particles appear to be disseminated throughout in this series. Besides the above localities washing is done in or near the Ingyi and the Sawme *chaung*.[3]

The Uyu Valley.—Gold-washing operations are carried on in the headwaters of the Uyu (Uru) valley between Lonkin and Mamon and again farther down near Haungpa.[4] The fine sand

[1] *Rec. Geol. Surv. Ind.* vol. lxii, 1929, p. 50.

[2] *Ibid.* vol. lxi, 1929, p. 56.

[3] *Ibid.* vol. lxiii, p. 36.

[4] *Ibid.* vol. lxii, 1929, p. 52; *ibid.* vol. lxiii, 1930, p. 35.

from the lower beds of the Uru Boulder Conglomerate is washed by Shan women, who can collect as a rule six to seven annas' worth of gold in a morning's work. During 1914–1915 an attempt was made by a Mr. Baldwin to win alluvial gold on a commercial scale at Mamon; about 100 oz., together with some platinum, are reported to have been obtained before the experiment was abandoned.

Farther down at Kyobin on the Uyu river old, high-level false-bedded, auriferous gravels occur. These, according to Maclaren, have for some generations been worked by the Burmese by a crude method of ground-sluicing. The gold of these gravels is brought down to this locality by the Chaungyi *chaung*, which drains the andesitic country from Banmauk to the neighbourhood of Kyaukpazat, and its gold is obtained by the wearing away of small pyritic gold-quartz veins described above.

Hukawng Valley.—Detrital gold is won in several places in the Hukawng valley along the banks of the Tanai *hka* and its tributaries. The more important localities[1] are:

1. Mashe Daru (26° 24′, 96° 36′) on the right bank of the Tanai *hka*, where there is a big sand bank close to the ferry.

2. The Tabyi *hka*, the sands of which are locally reported to be very rich in gold; washing is carried on wherever there is any accumulation of sand. The metal is generally in the form of coarse dust, but sometimes very tiny nuggets are also found.

3. Masumzup (26° 31′, 96° 59′), about one mile and five furlongs from the confluence of the Sumting *hka* with the Tabyi *hka*. The local Kachins informed the author that the sands here were even richer than those of the Tabyi *hka*, and one man working for a week is said to get a minimum of four annas' weight (approximately one-tenth of an ounce) of gold, while the maximum recovery for the same period during years of heavy rainfall is reported to be one rupee's weight (approximately two-fifths of an ounce) of gold.

4. The upper reaches of the Nambyu *hka*.

5. The Kapdup *hka* near and above the village of 'Nbawn (26° 21′, 96° 59′), wherever any accumulations of sand exist in the stream.

[1] *Rec. Geol. Surv. Ind.* vol. lxv, 1931, pp. 48-50.

Generally a test washing is made first, and if the experiment proves successful, systematic work is commenced, otherwise a search for a new locality is made. The Kachin slaves used to be employed in large numbers in washing for gold, but since their liberation and partial migration to administered country the industry has dwindled considerably.

Gold Workings in the Upper Tertiary Conglomerate.—In the area enclosed by the U-shaped bend of the Namgawn *hka* (26° 18′, 96° 29′) several old gold workings were examined by the author.[1] The usual depth of a pit is about twenty feet, while the maximum is about thirty feet, at which depth the influx of water prevents work, though it is locally believed that the gold continues lower down. The following is a representative section in a working :

1. Layers of sand or fine pebbly conglomerate, with a maximum thickness of three feet.
2. Conglomerate layer, consisting of big quartz and other siliceous boulders, with pebbles of volcanic rock which are considered as a favourable indicator for the occurrence of gold. This would perhaps show that the original deposit, by the degradation of which the gold found here is derived, was not unlike the Kyaukpazat deposit described above.
3. Overburden of earth, the upper portion of which is lateritised. Its thickness varies from three to ten feet.

Two men generally work together, and the maximum yield was locally reported to be about one and a half tolas (a little over ½ oz.) in six days, while the minimum is about one-third of the maximum given above.

Numerous old gold workings occur in the Upper Tertiary conglomerate (Tanai *hka* boulder conglomerate) in the neighbourhood of the Lunghkrut *hka*, a little west of Tari village (29° 12′, 97° 2′) and extend as far as the headwaters of the stream. The pits are about six feet deep, and the sands in which the boulders are embedded are washed for gold. Similar deserted workings occur a little west of Ngagahtawng (26° 11′, 97° 30′). The intercalated sand-rock, locally called *ja-sai*, which contains the gold, varies in thickness from a few inches to one foot. The author was informed that if a rich gold-bearing

[1] *Rec. Geol. Surv. Ind.* vol. lxv, 1932, p. 49.

sand is struck, four annas' weight (one-tenth of an ounce) of the metal might be obtained in one day.

Northern Shan States.—The gravels of some of the short, narrow and deep tributaries of the Salween in the Northern Shan States are known to be auriferous. The Nan-Hsawm, one of the longest, was in former days worked by Chinese, and in 1905 it was taken over by the Namma Gold-Dredging Company. A dredger was erected on the ground, but gravel and boulders embedded in a stiff clay, hardened by calcareous tufa derived from limestone forming the sides of the valley, were found not sufficiently loose to be worked in this fashion. The venture, therefore, proved a failure. The streams of the Wa country across the Salween opposite Namma are reported to be highly auriferous.

J. Coggin Brown (9) examined the alluvial auriferous deposits in Möng Lông State. He found them too poor to be worth exploitation, although small patches were found to contain occasionally over nine grains of gold to the cubic yard. The locality is difficult of access and the gravels are of limited extent. In the Hwe-gna-sang, which is the largest stream, draining the flanks of the Loi Sar, the deposits cover an area of 9½ acres only. Small patches of gold-bearing gravel certainly occur in some of the other streams, but they again are of very limited extent. The gold is derived from quartzites and chloritic slates, traversed by numerous quartz veins. Although the gold is coarse-grained and is sometimes found adhering to quartz, none of the veins, when tested, showed any trace of gold.

Loi Twang Gold Deposits, Southern Shan States.—Gold is found in the streams on the northern side of Loi Twang ridge, situated at the junction of the Möng Tung, Kehsi Mansam and Möng Küng sub-States, except those whose valleys are composed of shales associated with the sandstones. The gold, which is usually found in thin flat spangles with very irregular outlines and pitted surfaces, is associated with the sandstones, but the distribution in the rock is very irregular. According to La Touche (6), only in three of the streams, the Namhkam in Möng Tung, the Hwe Aw in Kehsi Mansam and the Nam Ka in Möng Küng, coarse gold occurs, and even in these cases is confined to a very small area. From a commercial point of view he considered this area valueless, as the quantity of gravel,

from which an average yield of more than a grain per cubic yard might be expected, is very small.

Karenni.—O'Riley obtained small quantities of gold in the Myet-nan-*chaung*, to the east of Toungoo. He was informed that the Burmese had obtained a considerable amount of gold here.

Lower Burma.—The gravels of the Sittang at Shwegyin were formerly washed for gold, and the industry, though unimportant, dates back to the times of the Burmese Kings, prior to the British occupation.

In the Tavoy district gold is reported from the Ye river and also from the Heinze basin. The various tributaries of the Tenasserim river, besides carrying tin, are also auriferous. Thin veins of auriferous quartz occur in Saba *taung* near the town of Tavoy.

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CHAPTER VIII

LEAD, SILVER AND ZINC DEPOSITS.

THOUGH lead-bearing minerals are known to occur at several localities in Burma, the lead-silver industry established at Bawdwin, in the Northern Shan States, ranks next in importance to the most valuable industry (petroleum) of Burma. Since these lead-silver deposits of Bawdwin constitute the most important in Burma, and in fact in the whole of the Indian Empire, they naturally deserve the first treatment.

Bawdwin, Northern Shan States.

Bawdwin (23° 7′, 97° 20′ 30″) lies in the Tawng-Peng State of the Northern Shan States and 50 miles from Namyao Station, on the Mandalay-Lashio branch of the Burma Railways. Namyao is connected to Bawdwin by a 2-foot gauge railway line. The hills around Bawdwin are bare of trees, owing to the destruction of the forest by the ancient Chinese miners, and also to the blighting effect of the flue gases. The total area of the concession is nearly 4 square miles and is drained by the Pangyun, a tributary of the Nam-Tu or Myitnge river.

History of the Mines.—It is believed that the Bawdwin mines had been worked by the Chinese since very early times, though it is not known when mining operations first commenced. It is certain, however, that they were working the mines in 1412 A.D. During the reigns of Chia Ching and of Tao Kuang (1796–1851 A.D.) the mines were extensively worked; but during the reigns of the succeeding kings, Hsien Feng and Tung Chih, which represented a period of civil war, and when the Tai-p'ing and Panthay rebellions broke out (the former over the greater part of China, the latter in Yunnan), the mines were deserted. The Chinese worked the mines with convict labour, and the

hill containing the ore-body is riddled with the small and tortuous windings of adits. The ore was smelted locally, and the remains of the furnaces are still to be seen scattered for miles along the banks of the Pangyun river.

The modern development of the mine may be said to have commenced in 1891, when Messrs. A. C. Martin and J. Sarkies applied for a lease of 4 square miles, and eventually formed the Burma Mines Development and Agency Company. This enterprise changed hands several times, and ultimately was taken over by the present company, the Burma Corporation Ltd. During 1904–1908 a narrow-gauge railway was built from Namyao to the mines, and the smelting plant was erected at Mandalay, which proved, however, too distant, and its place was taken by Nam-tu, only 12 miles by railway from the mines. In the beginning of this stage of development the slag left by the Chinese was smelted, but subsequently the ore-body itself was explored and struck by means of the "Dead Chinaman Tunnel" or No. 2 level. From then onwards the development was rapid.

Geology and Minerals.—The rocks occurring in the Bawdwin district comprise the slates, phyllites and greywackes of the Chaung Magyi Series, succeeded by rhyolites and rhyolitic tuffs of the Bawdwin Volcanic Series. The latter form an elongated dome surrounded on all sides by the rocks of the Pagyun Series, of late Cambrian or early Ordovician age. They form a variable series of shallow-water sediments, including conglomerates, grits, sandstones and shales, the last two often alternating.

The ore bodies occur in the Bawdwin Volcanic Series, in which coarse felspathic grits occur in association with inter-bedded acid flows and tuffs. These rocks have been intensely crushed and dislocated by the great Lilu overthrust which traverses the district. The main ore channel is situated in this thrust zone and has been traced for approximately 9,000 feet. Mining has revealed the presence of three ore bodies, the two most important being known as the "Chinaman" and the "Shan" lodes respectively. The latter appears to be a north-ward extension of the former, offset to the east by the Yunnan fault.

The ore-bodies are confined to the rhyolitic tuffs which

are underlain by a sedimentary bed, having an approximate thickness of 150 feet, and which was unfavourable for mineral deposition. Underlying the sedimentary deposit are found rhyolites again, the composition of which has proved suitable for mineralisation.

The Ore-channel.—The ore-channel is at least 8,000 feet long, with an average width of 400–500 feet. Three ore-bodies are known :

(1) A Western, also known as the "Burman" lode of the vertical shaft section, and the "Chinaman" of the Amphitheatre section. It is now believed that these two veins are parts of one original ore-body separated by faulting. The Burman lode is a thin, regular vein of lead, silver and zinc ores, and the "Chinaman" an enormous replacement deposit of zinc-lead-silver ore.

(2) A Central, otherwise called the "Shan-Palaung," lode. It runs parallel to the Burman lode, and is 130 feet to the east of it.

(3) The Eastern or "Kachin" lode. It is little known at present.

Only the "Chinaman," "Burman" and "Shan-Palaung" lodes have been developed up to the present.

Chinaman Lode.—The Chinaman lode has been developed for considerably more than 1,000 feet, and its width varies from a few feet to more than 100 feet. It has, on some levels, an average width of 50 feet of solid sulphides over a distance of 1,000 feet. According to M. H. Loveman (11),[1] it is primarily a zinc-lead-silver ore-body with small amounts of copper along the edges. The central core consists of solid galena and sphaelerite. On either side of the core bands of solid ore and mineralised tuff alternate. The galena and zinc-blende are intimately intergrown and are of fine to medium grain. The ore grades in both directions from these fine, minute intergrowths to solid masses of earthy blende with patches of hard, dark sphaelerite, to pure, coarse galena. The core is extremely rich. In the second-grade ore, the galena is seen replacing the altered felspar of the rhyolite tuff, or even its groundmass, while both galena and zinc-blende form numerous ramifying veinlets crossing the

[1] See list of references on p. 152.

rock in all directions and leaving little except the original irregular quartz grains, which in the massive ore are replaced too.

Other minerals found at the mine are cerussite, anglesite, pyromorphite, chalcopyrite, chalcocite, covellite, melaconite, malachite, azurite, native silver, native copper, barytes, haematite, limonite, erythrite, calamine and sulphides of nickel and cobalt.

Origin of the Ores.—The ores have been deposited by ascending thermal solutions containing sulphides of lead, zinc, silver and copper which brought about the metasomatic replacement along an extremely faulted, shattered, crushed and sheared zone of rhyolitic tuffs. These solutions emanated from the same source as the rhyolites, which are believed to be connected with the Tawng-peng granite batholith of enormous size. In regard to the sequence of deposition, galena seems to have been deposited first and replaces the altered felspar in the tuffs. Zinc-blende forms branching veins, leaving little except irregular grains of quartz. The rocks seem to have undergone a general silicification and sericitisation. Later alterations and oxidation have had a profound effect upon the upper part of the ore-body as it had been honeycombed for centuries by Chinamen, thus providing easy access to the weathering agents: the area experiences a sub-tropical monsoonal climate.

Ore Reserves.—The table[1] on page 144 gives the ore reserves of the mine as on 1st July, 1928. It shows the quantity of proved and probable ore in the Chinaman, Shan and Palaung lodes, and also the quantity that had been extracted up to this date. The average assay values are also given. Included in these ore reserves are approximately 350,000 tons of copper ore averaging about 13 per cent. lead ; 8 per cent. zinc ; 7 per cent. copper ; and 18 ozs. of silver to the ton.

Output.—During the quinquennial period of 1909–13, the production of lead from the Bawdwin mine was 46,000 tons ; during the next period, in spite of the War, 73,817 tons of lead were extracted, and in the following quinquennium the production of lead had risen to 161,902 tons. During the period 1924–28, the quantity of lead obtained has increased to

[1] *Quinquennial Review of the Mineral Production of India* for 1924-28, *Rec. Geol. Surv. Ind.* vol. lxiv, 1930, p. 160.

	Tons	Average Assay Value			
		Silver. Ozs.	Lead per cent.	Zinc per cent.	Copper per cent.
Total Chinaman ore-body (proved and probable) - -	5,470,066	23·5	27·3	17·4	0·49
Total Shan lode -	1,260,236	17·8	19·7	10·3	3·60
Total Palaung lode -	14,910	26·6	11·7	11·0	8·80
Total (proved and probable) - -	6,745,212	22·4	25·8	16·0	1·10
Extracted - -	2,652,461	23·8	25·7	16·0	1·01
Reserve in mine -	4,092,751	21·5	25·9	16·0	1·15
Ore stocks - -	6,933	20·5	15·0	7·8	5·60
Total ore reserves -	4,099,684	21·5	25·9	16·0	1·16

297,715 tons, valued at Rs. 11,24,41,670 (at par value Rs. 15 = £1). It is noteworthy that there has been a steady increase in production except in 1925, when there was a small decrease due to mine fires.

Mawsön, Southern Shan States.

Lead-ore deposits occur at Bawzaing (20° 57′, 96° 50′), in the Southern Shan States, east-south-east of Mawsön, which is connected with the Southern Shan States railway at Heho by a motor road, 19½ miles in length, and from it a private road covers the intervening 2 miles to the mine.

Geology.—According to J. Coggin Brown (22), there are three sedimentary bands of brown sandy shales, marls or brown or reddish sandstones, running approximately from north to south and dipping in an easterly direction in the Upper Ordovician limestones of the Bawzaing lease. They merge by insensible gradations into the limestones above and below them. Adjacent to their veinlets and stringers of galena, there is some evidence of dolomitisation of the rock ; but farther away from them this is not well marked. Siderite has been deposited in the country rocks in the vicinity of the ore channel.

The Ore-body.—The main ore-body of the Bawzaing mine occurs in a wide, irregular fissure with ragged walls, and extends north 20° west, obliquely across the strike of the surrounding rocks. It does not follow their dip, which is towards the south-east at angles varying from 30° to 60°, while its own general inclination is only a few degrees on either side of vertical. The fissure is filled with mineralised clay containing very numerous irregular blocks of limestone of all sizes.

The ore-shoot within the fissure zone has a decided pitch to the south and has been opened up by two shafts known as the Bawzaing and Theingon shafts. The ore-shoot had a maximum width of 70 feet, in the Bawzaing shaft at about 75–80 feet below the surface. It was encountered in the Theingon shaft at a depth of 124 feet. It varies between 175–250 feet in height, displays a roughly lenticular section, and as at present developed, has been followed for 700 feet down the pitch with little variation in values.

A second ore-channel, known as the "North Lode," which is more or less vertical, is known to exist, but is at present imperfectly explored. Its galena is much more platy in character and is found in clay as usual.

The known ore reserves in April 1930 were officially placed at 185,400 tons, and they average more than 7 per cent. of lead.

The galena is irregularly distributed in the clay, which is of variable hardness and plasticity. It is possible sometimes to trace an enriched, lead-bearing zone for 20 feet or so, while the seams and stringers of galena with oxidised lead minerals can be followed between the limestone blocks, as though still *in situ*.

The ore-bearing clay is easy to concentrate, the only metallic minerals of economic importance in it being galena and cerussite; it is almost free from zinc and copper compounds. Typical buyer's assays of the concentrate are given below:

Over ¼-inch material		Under ¼-inch material	
Lead - - -	75 per cent.	Lead - - -	60 per cent.
Silver - - -	14 ozs.	Silver - -	8·8 ozs.
Zinc - - -	0·30 per cent.	Zinc - - -	0·30 per cent.

Treatment of the Ore.—On arrival at the surface the large pieces of limestone are eliminated and the nodules of galena are washed from the adhering clay and picked out, and after drying

are bagged for transport. This product is stated to contain 75 per cent. of lead or more; while the "fines," which pass the screen, are concentrated to a 70 per cent. lead product by washing in sluices and hand-jigging the concentrate so obtained. With regard to the fine lead content of the clay itself, it is noteworthy that, whether the clay is unctuous or crisp and cellular, it is recoverable to the extent of only about 50 per cent. The remainder is assumed to be carbonate slime.

The angular character of the rock waste from the washing plant is very noticeable and disproves the migration of the ore-channel from any distance. J. Coggin Brown (22) has stated that at several places he observed the ore *in situ*. The mineralisation has apparently taken place in both the more massive limestones and in the thinner platy beds, which approach calcareous shale in composition, where they adjoin the fissure walls. It is noted that the values tend to be richer in proximity to the walls, and the mineralisation disappears a short distance away from the fissure. Moreover, the galena nodules are exceedingly irregular in shape and vary in size from that of coffee beans to exceptionally large masses weighing one or two hundredweights. According to W. H. Rundall (21), the ore sometimes at comparatively shallow depths is found as irregular veins and pockets of solid galena in hard ferruginous limestone, with all the gangue in the immediate vicinity of these so completely decomposed that quantities can be pulled down by the hand and the larger nodules of galena picked out and completely freed from gangue, if dry, by a shake or two.

Origin of the Ores.—The galena-barytes veins of Thaungdwin and elsewhere in Mawsön, in the opinion of J. Coggin Brown (22), are probably of aqueous origin and owe their presence at the surface to the insolubility and resistance to weathering of the hard, massive, coarsely crystalline barytes in which the galena occurs as anastomosing veinlets and irregular segregation patches.

The ore-bearing zones of Mawsön, on the whole, occur in somewhat parallel belts, some hundreds of feet in width, which extend for several miles from north to south, and are easily located on the surface by the remains of ancient workings that penetrate into them. A preliminary examination has shown

that there is an intimate connection between these lines of old workings and certain well-defined horizons of soft sandstones and sandy shales, which are interbedded with the Upper Ordovician limestones of the region, known as the Mawsön Series.[1] The former rocks are largely the decalcified surface representatives of impure limestones, calcareous shales and sandstones. The general dip of the more important horizons on the east of the Mawsön dome is to the east; and J. Coggin Brown (22) advances the theory that, although the sandstones and shales have not completely prevented the ascent of the ore-bearing solutions, they may have acted at least partly as impervious barriers. If this be true, the most favourable occurrences of the original ore-bodies will be in the upper parts of the limestone bands which occur underneath the sandstones and shales.

The deposits at present available for investigation are profoundly modified by sub-surface alteration. They all occur within the zone of weathering, the depth of which is limited by the distance to which surface water and free oxygen can penetrate in large quantities. Most geologists, who have examined the ore-deposits of Mawsön, are agreed that they lie in sparsely mineralised zones, which have been subjected to much brecciation and more decomposition. It is not known, however, whether the ore-bearing clays associated with the deposits under exploitation, occur *in situ*, or whether they owe their origin to the downward movement of residual deposits and their distribution along pre-existing underground pipes and channels. W. H. Rundall (21) described the sequence of events leading up to the irregular impregnation by galena, which forms the ore-bodies, as follows:

(1) Raising of the limestone mass by the intrusive granite at the edge of the plateau some 40 miles to the west.

(2) Folding of the limestone with the development of zones of fracture, owing to uneven stresses during and after the intrusion of the granite.

(3) The ascent of the mineral-bearing solutions from the underlying granite magma along some of the major north-south fractures which coincide with the strike of the strata,

[1] Chhibber, H. L., *Geology of Burma*, 1934, p. 145.

and dispersal along certain zones of cross-fracture and shattering. Deposition of minerals in the fractures and by replacement of the limestone, with occasional localisation and concentration of the minerals in special zones and channels, owing to the impounding action of the beds of shale.

(4) The thermal activity which introduced the minerals was followed by descending meteoric waters, leading to decomposition and solution of the limestone along the fractured zones and to further movement and fracturing due to shrinkage and subsidence.

The mountains of the Shan plateau were upheaved in late Cretaceous—early Eocene times, and the intrusions of granite magma also took place at about the same time. Morrow Campbell was also inclined to agree with W. H. Rundall's views, stated above, but considered that the ore-bearing clay is a fine residue from the dissolution of the limestone, that it was not produced *in situ*, but has been carried down from above. Coggin Brown, however, has challenged this hypothesis, and is inclined to believe that at least the greater part of the ore-bearing clay was formed *in situ*. His tentative opinion is that the Bawzaing deposits are more closely allied to those world-wide deposits of lead ores in sedimentary rocks that have apparently originated independently of igneous activity, rather than to others that are believed to be directly related to igneous sources. Amongst their characteristics, their occurrence in brecciated zones of limestones and associated rocks and in pipes and channels may be noted. To some extent he considers the deposit to be of metasomatic origin, for the galena certainly occurs at times disseminated in limestone. The fact that the mineralisation has occurred along rock-openings, partially determined by the prevailing joint-system is proved by the characteristic form of many of the nodules of galena. Whether the major channels of ore-deposition are connected with the larger joint systems or dependent on faults or other fissures is not known yet.

Silver Content of the Bawzaing Ore.—The silver content of the ore is very variable, ranging from 10 ozs. to 70 ozs. to the ton of lead. In a series of thirteen assays of ores from various parts of Mawsön made by a reliable firm in England, the lowest value was 12 ozs., the highest 45 ozs., and the average, 22 ozs. of silver per ton of lead.

Lead Content of the Ancient Slags.—The ancient slags in the neighbourhood of Bawzaing carry, on an average, upwards of 30 per cent. of lead, but little silver. This is obviously due to the fact that the ancient workers extracted silver and had little use for lead. A series of assays of samples collected by E. L. G. Clegg, made in the laboratory of the Geological Survey of India in Calcutta contained 23·04 per cent. to 41·18 per cent. of lead, while two assays of mixed slags yielded 36·50 and 38·22 per cent. of lead.

Pindaya State.

Galena is found in stringers and thin veins in the argillaceous limestone forming the steep hill one mile to the south-east of Alechaung [1] (21° 0′, 96° 33′). A few old workings exist in the vicinity, and pieces of slag are found in the stream bed below the hill.

North-eastern Putao, Myitkyina District.

The galena deposits of North-eastern Putao occur in the Nam Tamai, Nam Tisang, and Upper Nam Kiu valleys, in the extreme north-east of Burma on the China-Tibet frontier. The area lies between 97° 30′ and 98° E. long. and 27° 30′ and 28° N. lat. The Nam Tamai valley is strewn very sparingly with isolated occurrences of lead " slag " of small size and no importance. In the Nam Tisang valley one locality was worked by Chinese for a few months only.

According to Murray Stuart (16) an old galena mine occurs in the northern side of the Pyit Wang. It is situated about 4 miles up the stream, above its junction with the Nam Tamai, and is high up on the left side of the gorge, about 1,000 feet above stream level, in a highly siliceous limestone. The mine is a natural cavity. The country rock is traversed by very thin veins of galena, while particles of galena and pyrites are scattered in the rock. Murray Stuart did not consider the deposit of any economic value.

Another mine, known as the Sheng Wang Mine, occurs in a vein of ferruginous material in siliceous limestone, and the

[1] *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, p. 63.

vein has been completely worked out. Other lead occurrences in this area comprise those of the headwaters of the Gum Ti and the Nam Lang. Summarising the prospects of these occurrences, Murray Stuart stated that the amount of lead slag is insignificant, while the galena deposits are of no economic value, and at present are almost inaccessible.

Lagwi Pass, Chinese Frontier.

Near the Lagwi Pass on the Chinese frontier, lead-ore occurs at the junction of siliceous tuffs with an altered limestone at an altitude of about 11,000 feet above sea-level. The author visited the locality in 1930, and found that pyrite and chalcopyrite also occur. The silver content is low, and since the locality is difficult of access, the deposit is of no immediate importance.

Wanghte, Htawgaw Subdivision, Myitkyina District.

The author [1] found old Chinese workings for lead ore in limestone near the village of Wanghte (25° 50′, 98° 8′) in the Htawgaw subdivision of the Myitkyina district. However, the locality does not seem to possess any commercial importance.

Bhamo District.

The silver-lead mines of Penshi (24° 27′, 97° 41′) were formerly worked by the Chinese. They are situated in a hill formed of crystalline limestone, about 600 feet in height, on the left bank of the Taiping river. The ores occur in fissures in the limestone filled with clay, and were reached by adits from 200–400 feet in length.

Katha District.

Noetling (8) found veins of cerussite traversing a band of aphanitic rock at Kaydwin (24° 15′, 95° 40′) on the Nam-maw river. The average thickness of the band is about 4 feet, and cerussite occurs in thin layers along the cracks in the rock. Samples of the ore yielded on assay 69·1 per cent. of lead and 33 ozs. 16 dwt. 4 grains of silver per ton of lead. Another

[1] *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, p. 63.

similar occurrence exists at Mawkwin (24° 10′, 95° 37′), six miles to the south-west of Kaydwin.

Lead ore is also known to occur in the Mandalay and Toungoo district.

Mount Pima, Yamethin District.

A lode of argentiferous galena 3 to 30 feet thick is reported to occur in limestone among the foothills of Mount Pima. It was worked by a company in 1908, but the ore-body was found to be merely a pocket and the supply was exhausted. An output of 2,463 tons of ore was returned for the year 1909.

Salween District.

According to O'Riley (1) and Theobald (4) lead ore is known to occur in the Yunzalin valley of the Salween district. The ore is said to occur in the same limestone formation as exposed near Moulmein. The ore near Mizine occurs in a siliceous gangue, very difficult to work, and yielded on assay 14 ozs. 14 dwt. of silver per ton of lead. These localities, however, have not been visited since 1873, and nothing is known of the economic importance of the deposits.

Amherst District.

O'Riley (1) mentions the occurrence of galena in the Kamawkala limestones between the Dawna Range and the Thaungyin river, but the exact locality is not known.

Tavoy District.

In the Tavoy district galena occurs in small quantities at the Hermingyi, Pagaye and Kanbauk mines. A quartz vein carrying galena crops out in the Mergui Series on the road between Uthayan and Wumpo.

Mergui District.

Galena is associated with the igneous intrusions—granite, pegmatite, quartz-porphyry and quartz veins—of the Mergui district. The largest deposit occurs on Maingay Island, west of King Island. The occurrence here is in the form of a vein which

runs out to sea in a direction north 35° west, dipping about 15° to the south, and is traceable inland for about 130 feet. An adit was driven to a distance of 30 feet into the hill. The galena is somewhat " bunchy " and about 2 feet wide, and appears to disappear inland. The veins over the hill do not thicken and are seldom more than an inch or two in width. It was suggested by J. A. Page, who first examined the locality, that detailed examination was necessary to decide the question of economic working of the lode now submerged under water. Specimens from this locality, as analysed in the Geological Survey of India laboratory, contained 7·45 per cent. of lead and 17 oz. 12 dwt. 19 grains of silver per ton of lead. There are some stringers of massive galena in the quartz veins, the average percentage of galena ranging from 3 to 10 per cent.

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CHAPTER IX

PETROLEUM.[1]

A Brief Description of the Existing Oil Fields.

THE oil fields of Burma are found as a long line running from north to south near the centre of the synclinal trough which forms the centre of Burma. It may be said at once that the important fields (*a*) lie near the centre of the trough, (*b*) are on gently folded anticlines—puckers in the synclinal trough.

There are half a dozen quite minor fields, and it is found that these either (*a*) are slightly away from the centre of the trough, or (*b*) are highly folded, or irregular, structures. All the oil-bearing beds were laid down in the western half of the gulf.

1. Indaw.

Indaw is the northernmost field of the central tract of Burma and is 175 miles north of the other northernmost producing field, Yenangyat. Naturally its discovery caused considerable surprise in the days when it was thought that the oil-bearing rocks of Burma were on one definite horizon. It is said that one well-known geologist, still alive, volunteered to drink every drop of oil which should be obtained in this field. Production was first recorded in 1918, and has since shown a steady though not phenomenal rise. To the end of 1931 the production was about 23,000,000 gallons. It is a fine gently folded dome with a considerable gathering ground. The actual producing area is about a quarter of a square mile, and the oil sands occur between 800 and 1200 feet. To the end of 1931, 41 wells had been drilled in the proved area, but no oil sands below the 1,200 feet have been proved. Tests have been carried down

[1] This chapter is by Dr. L. Dudley Stamp, to whom the author is grateful for this contribution.

to over 3,000 feet, but deep drilling has been hindered by very heavy gas. Owing to remoteness of the field it has not been possible to utilise the gas resources, estimated at over 12 million cubic feet per day. As in most of the Indian fields, the conservation of gas pressures is regarded as of the utmost importance, and it must be regarded as due to this that well No. 1 of the Indaw field has given an almost steady yield for over 15 years. The future of the field lies, however, in the possibility of locating new deep sands. It lies in the wet zone of northern Burma, and considerable difficulty has been experienced with fever. The oil obtained is refined at Pantha, 22 miles distant on the river Chindwin, whence it is sent down the river, and supplies, as kerosene, the local markets of Upper Burma. The production at Indaw is shown in the following figures :

	Gallons.		Gallons.
1918	473,800	1925	1,385,977
1919	1,085,030	1926	1,255,840
1920	1,022,766	1927	1,825,210
1921	1,182,782	1928	2,308,880
1922	1,210,914	1929	2,796,560
1923	1,311,664	1930	2,858,096
1924	1,474,898		

The rocks in the central trough of the Chindwin basin are unconsolidated sands with pebbles and pebble beds, which lithologically resemble the Irrawaddian farther south, and are roughly of the same age. Underlying these and exposed on the Indaw dome are the equivalents of the Peguan—it is from the lower members of these that the oil is obtained.

2. Yenangyat.

Yenangyat and Singu should, geologically speaking, be described together, since they form part of one long anticline about 30 miles from north to south, and striking a few degrees west of north. The fold is, however, breached by the Irrawaddy : Yenangyat field lies to the north ; Singu field to the south (see Fig. 4). Like many of the folds of Central Burma the Yenangyat-Singu structure has a gentle westerly limb and a steep, almost vertical, easterly limb. Indeed, in the case of Yenangyat the eastern limb is slightly overfolded. The position

of the two main fields on the fold is determined by the presence of crest-maxima. The rocks brought up by the fold are Peguan in age, the surrounding rocks being the barren fresh-water Irrawaddian sands. The Peguan rocks themselves pass steadily northwards into fresh-water deposits, and at the northern end of the Yenangyat fold this change may be seen taking place. This is one reason why the northern end of the fold is non-productive, and seems also to account for the rapid exhaustion of the northern of the two fields—Yenangyat.

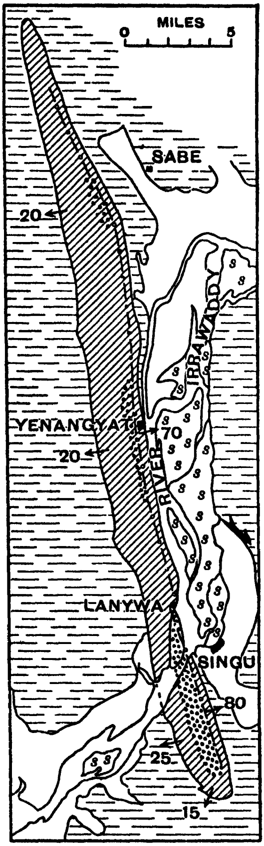

FIG. 4.—Sketch-map of the Yenangyat-Singu oilfields, showing the long narrow fold of the Pegu Series (diagonal lines) surrounded by Irrawaddian (horizontal lines). The coarse dots show the approximate limits of the oilfields. *ss* are sandbanks. The dips shown are generalised and apply to the highest Pegus.

The fold has been more extensively denuded at Yenangyat than at Singu, and many of the productive sands of Singu outcrop at Yenangyat. This is another reason for the poverty of Yenangyat when compared with Singu.

The Yenangyat fold gives rise to a long line of barren but picturesque hills forming the right bank of the Irrawaddy for many miles. They were visited by Dr. Thomas Oldham in 1855, and he suggested that the oil might be worth exploitation. Burmese hand-dug wells were commenced a few years later. The Burmah Oil Company first commenced operations around Yenangyat village in 1891, and oil production was officially recorded for the first time in 1893. Later in the field were the Rangoon Oil Company (B.B.P.) and Minbu Oil Company. The story of exploration has been told by Pascoe in his memoir, and need not be repeated here. It was gradually found that the commercially valuable field was restricted to the crest maximum of the fold which is attained in Blocks 9 and 8. Of the valuable

area the B.O.C. held Blocks 7, 9, 12; the Rangoon Oil Company Blocks 8, 13, and B and C; the Minbu Oil Company Blocks 10 and 33. Many of the wells gave a high initial yield—as much as 30,000 gallons in the first 24 hours—but the yield dropped rapidly, just as that of the field as a whole has done. The Yenangyat and to some extent the Singu oils are richer in the lighter hydrocarbons than are the Yenangyaung oils. The B.O.C. oil is sent to Singu by means of a 4-inch pipe-line, Singu being connected with Yenangyaung by an 8-inch line.

Production at Yenangyat (including Sabè)

	Gallons.	
1893	163,794	
1898	6,550,422	
1903 (peak)	22,668,312	
1908	6,578,850	
1913	5,499,191	
1917	6,700,000	
1918	4,739,587	
1919	4,123,387	
1920	3,176,231	
1921	2,510,533	From 1921 the production from Lanywa is included
1922	2,413,416	
1923	1,700,035	
1924	1,594,517	
1925	1,562,444	
1926	1,778,041	
1927	1,844,946	
1928	3,072,222	
1929	17,606,935	
1930	19,877,276	

In the northern part of the Singu-Yenangyat fold there is another crest maximum west of the village of Sabè, in Blocks 57, 60 and 67. The B.O.C., R.O.C., and M.O.C. were all interested in the field, but a few initial high yields rapidly declined, heavy gas was encountered, and this is one of the regions of Burma which has been troubled by a yield of emulsion. The field has never been important; its small production, which was first recorded for 1907, is included in the figures just given for Yenangyat. Though structurally distinct, the fields of Lanywa, Yenangyat and Sabè all lie in the Pakokku district, and their productions are not, therefore, separately recorded in Government returns.

3. Lanywa.

From its position Lanywa might be considered as the southern part of the Yenangyat field, but it is structurally the northern part of the Singu field, which lies on the other side of the river Irrawaddy. The Singu field is abruptly truncated at the northern end by the river Irrawaddy, which there sweeps across from north-east to south-west. Obliquely opposite the Singu field there is the small Burmese village of Lanywa, and south of Lanywa in the dry season there has for many years formed a sandbank, since the bend in the river causes the main current to hug the southern shore against the Singu field. It was felt many years ago that if drilling through the sandbank were possible the northern continuation of the Singu field would be struck. A well was put down in great haste, but failed to strike oil before the high water season came on, and the rig had to be hastily removed, so hastily that the pipe was not withdrawn, and one of the steamers of the Irrawaddy Flotilla Company caught on the projecting head of the pipe, with the result that very serious discussions ensued. The Indo-Burma Petroleum Company tested the area as far as possible by putting down three or four wells near the village of Lanywa itself, where the sandbank adjoins the northern bank of the river, and from the results obtained there, and a careful geological examination of the area, decided on the enormous project of walling in the sandbank. The present writer was one of the geologists who reported on the scheme, and the building of the wall was actually carried out in three stages in the dry seasons of the years 1925-6, 1926-7, and 1927-8, reaching completion in 1929. The construction of the wall was facilitated by the occurrence of reefs of hard rock jutting out from the shore in the desired direction just where it was necessary that the wall should commence. Quantities of stone and rubble were available from other hard bands in the Peguan rocks. The success of the scheme is evident from the jump in production from a few thousand gallons in 1928 to about 16 million gallons in 1929, and this may be regarded as the most important of recent developments in production in Burma. By the end of 1930 there were 17 producing wells and 6 in progress, and the

production in that year was 444,000 barrels, or 17,760,000 gallons entirely from one horizon—the 1,700-ft. zone. Development has been slowed down in 1931 and 1932, but theie are big reserves. It is now certain that the main Singu oilfield extends *under* the Irrawaddy river, something like 400 acres of very rich oil land being covered by water even in the low water season. Schemes are in hand for tunnelling under the river and for erecting derricks in the tunnels.

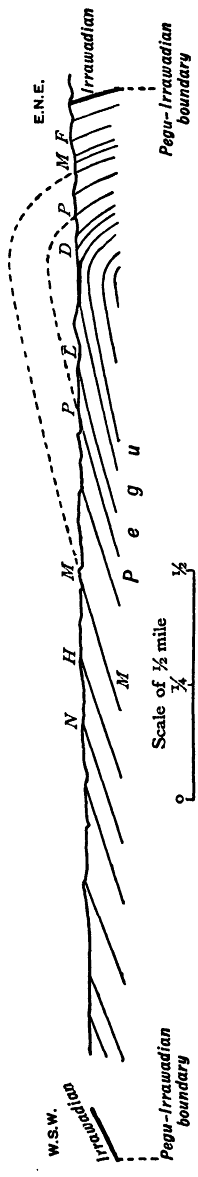

FIG. 5.—Section across the Singu anticline (N. of Moksomakon).

4. Singu, or Chauk.

Although the oil possibilities of Yenangyat were recognised as long ago as 1855 by Dr. Thomas Oldham, the father of the Geological Survey of India, it was not until 1897 that G. E. Grimes examined the Singu area and recognised its possibilities shortly before he became a victim of cholera. Production was first recorded in 1902, and the bulk of the development has been by the Burmah Oil Company. A neglected southern block, some way down the somewhat steep southern pitch, being despised by the Burmah Oil Company, was taken up by the Rangoon Oil Company, and somewhat unexpectedly yielded oil at depths of from 3,000 to 4,000 feet. This production is now controlled by the British Burmah Petroleum Company. The figures show that Singu has been steadily and economically developed. In the part of the field (the major part) operated by the Burmah Oil Company drilling is much less intense than at Yenangyaung, and the production of the field is regulated according to the requirements of the refineries at Rangoon, and thus depends

largely on the output from Yenangyaung. There are very good reserves, and the field may shortly become the biggest producer in Burma. At present the annual production averages 100,000,000 gallons. A pipe-line runs from Singu through Yenangyaung to Rangoon. Recent developments in the field have included electrification of most of the field; construction of underground storage for surplus gas. A test well in a southern block became at over 6,000 feet the deepest in Burma. A section across the field is depicted in Fig. 5.

Production of Singu (in gallons)

1902	245,390	1917	85,639,166
1903	5,617,371	1918	61,035,982
1904	23,549,759	1919	93,626,506
1905	37,452,055	1920	95,256,753
1906	34,843,621	1921	104,167,749
1907	43,543,566	1922	92,107,998
1908	43,048,948	1923	87,476,474
1909	37,169,061	1924	79,938,430
1910	31,524,175	1925	95,262,519
1911	50,564,755	1926	95,745,504
1912	56,645,200	1927	98,691,437
1913	63,538,710	1928	113,986,736
1914	73,409,518	1929	91,481,726
1915	77,005,880	1930	95,368,470
1916	44,105,013		

5. Yenangyaung.

Yenangyaung is the best known of the Burmese fields, and for that reason will be but briefly considered here. Its picturesque Burmese name, signifying "stinking water creek," or really "oil creek," indicates that the occurrence of oil was known long before the days of the modern oil-industry. Indeed. oil has probably been worked for many centuries, and was certainly being obtained by the Burmans at the end of the eighteenth century. The field was mentioned by Major Michael Symes in 1800, by Captain Hiram Cox in 1825, and by John Crawfurd (with an account of fossils by Dr. Buckland) in 1829. But the first really scientific observations were made by Dr. Thomas Oldham in 1855, and to Dr. Oldham belongs the honour of being the first to recognise the connection between anticlinal structure and the accumulation of oil. The Yenangyaung field

lay in the independent kingdom of Burma until the annexation of that kingdom to British Burma in 1885.

The early history of the field and its development up to 1909 have been ably summarised by Sir Edwin Pascoe in his well-known work, *The Oil-Fields of Burma*, and there is not much which can be added, apart from details, to his account of the geology of the field. Before the advent of the Burmah Oil Company large quantities of oil were won by the Burmans from hand-dug wells. Indeed, the table given below shows how important this production has been until quite recently. The wells were really shafts, 5 feet square, lined with planks, and actually reached depths of over 400 feet. The well-digger was let down by a rope passing over a pulley, and he worked frantically for about half a minute in the gas-laden atmosphere before being hauled to the surface for a prolonged rest. Even at the present day a few hand-dug wells survive amidst the forest of derricks. The oil is hauled up by a few coolies running down an incline suitably placed from the well and pulling with them a rope over the pulley. The oil so obtained is sold to the Burmah Oil Company. Such methods of oil-winning are archaic and laborious in the extreme. In the past at least one noteworthy labour-saving device, resulting also in a very marked increase in yield, has been tried. That is the construction of a side gallery from the hand-dug well to the carefully bored pipe of a near-by tube well!

During the Burmese régime two petroliferous tracts—Bêmé and Twingôn—were worked, and the right to mine was granted to twenty-four heads of families known as Twinzayos. A twinzayo could allot sites to any member of his family, but could sell his right only with the consent of the whole body of owners. When Upper Burma was annexed in 1885 the rights of the twinzayos were recognised. The Twingôn and Bêmé Reserves were demarcated, the former containing 295 acres, the latter 155 acres. By fixing the minimum distance between wells at 60 feet, over 4,000 well sites were determined. The wells belonging to King Mindon, which he had acquired by marriage with a female twinzayo or by mortgage, and 27 wells whose owners could not be found, fell to the Crown, and these 164 State wells were leased to the Burmah Oil Company. The

Burmah Oil Company was formed in 1886, though their managing agents, Messrs. Finlay, Fleming & Company, had previously traded in oil at Yenangyaung. The first well was commenced in 1887 in Khodaung, and it was not until 1906 that a second producing company appeared. The whole of the production from machine-bored [1] wells between 1888 and 1906, inclusive, was the production of the Burmah Oil Company. In the interval, however, the Burma Oil Syndicate had drilled unsuccessfully in the south (Blocks 1s and 2s) in 1890, and a subsidiary of the Standard Oil Company made an unsuccessful attempt to enter the field in 1901. Late in 1906 the Rangoon Oil Company (now a subsidiary of the British Burmah Petroleum Co. Ltd.) began to lease wells from the twinzayos and commenced drilling and production in 1907. Very soon the competition to secure well sites from the twinzayos in the Bêmé and Twingôn Reserves became very fierce, with the result that some parts became very congested indeed (see Plate VI, Fig. 1). It is only in these reserves that competitive drilling is possible ; the remainder of the oilfield, or at least Khodaung and Blocks 1N and 2N, being leased to the Burmah Oil Company. The price asked by the twinzayos for their well sites rose rapidly from Rs. 20 to Rs. 100 in 1895 to Rs. 5,000 in January 1907, and to about Rs. 50,000 in 1910. There are now practically no well sites of value available. In April 1907 drilling was commenced by Messrs. Jamal Brothers & Co.—whose oil interests were afterwards merged with those of Messrs. Steel Bros. & Co. as the Indo-Burma Petroleum Co. Ltd. Messrs. Steel Bros. & Co. Ltd. remain the managing agents of this prosperous oil company, as well as of the Attock Oil Co. Ltd. which operates in the Punjab. The Nathsingh Oil Company was floated in April 1908, the British Burmah Petroleum Co. Ltd. at a later date (1910). It is unnecessary to do more than mention various smaller or short-lived companies, such as the Twinza Oil Co. (T.O.C.), United Twinyo, Aungban Oil Company, and Anglo-Burman Oil Co., but of greater vitality is the Yomah Oil Co. (1920) Ltd. The expensive purchase of almost valueless sites

[1] The system of drilling usually used is the percussion or cable system ; rotary drilling has been tried, sometimes successfully, on some of the fields, especially for the shallow wells.

PLATE VI.

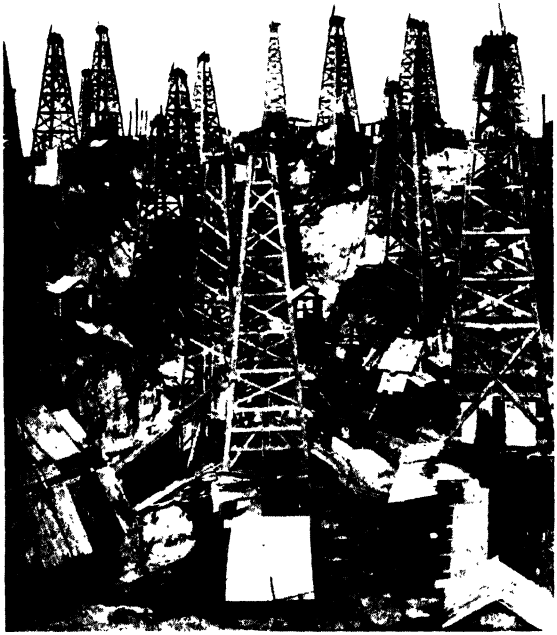

FIG. 1.—A NEAR VIEW OF PART OF YENANGYAUNG OILFIELD.
Notice the congestion of derricks.

by the ill-fated Indo-Burma Oilfields (1920) Ltd. still lives as an unpleasant memory with those who contributed towards the initial £2,000,000 capital of this company. Several syndicates have been interested in various ventures from time to time ; in particular, the possibility of striking deep oil to the southern end of the field, south of the preserves of the Burmah Oil Company, has always been an attractive speculation. The idea developed that mud veins might have sealed off a southern extension of the field and, after several tests, great excitement was caused in 1930 by the striking of a 100 barrel-a-day sand at 4,000 feet, nearly a mile to the south of the old producing area. This means a new lease of life for the field.

The oil of Yenangyaung is sent to Rangoon for refining. The Burmah Oil Company have a 10-inch pipe-line, 300 miles long, from Yenangyaung to their refineries at Syriam on the Rangoon river. The Indo-Burma Petroleum Company sent their oil by barges or "oil flats" to their refinery, also at Syriam, but lower down the Rangoon river.

Geologically, there is little to add to Pascoe's account of the Yenangyaung field. Structurally, it is a fine elongated dome (see Fig. 6). In searching for reasons for the prolific yield and long life of the field there are several aspects to be considered:

(*a*) Yenangyaung lies right in the heart of the western of the twin gulfs of Burma, in a position where the "inter-

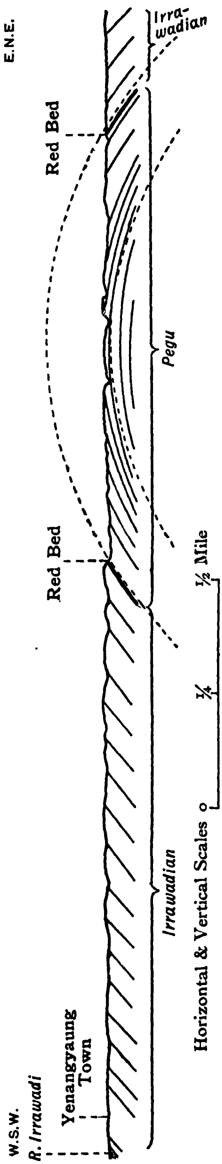

FIG. 6.—Section across the central part of the Yenangyaung anticline. The anticline has recently been shown to be slightly more asymmetrical than is shown in this section.

mediate" conditions necessary for oil formation persisted longest. Thus oil sands are worked at all depths from the surface to more than 4,000 feet. One may hazard the suggestion that this thickness represents the accumulation of a quarter of a million years. The favourable conditions extended as far north as Singu, but northwards the beds rapidly become more continental in character. South of Yenangyaung the oil-bearing horizons pass rapidly into barren marine clays and sandy clays on the same horizon (see below under *Minbu*).

(*b*) The irregularity in the yield of neighbouring wells and the extreme difficulty in the correlation of sands is largely a function of the lenticular nature of the individual sands. In some cases a lenticle of sand may really have formed a closed reservoir of oil, and when struck gave a large initial yield which rapidly dropped. Pascoe pointed out, however, that one well might strike an oil sand in a very porous part, so that the flow of oil from the immediate neighbourhood would be at first extremely rapid, resulting in such a diminution of pressure as to affect the yield in a very short time. On the other hand, another well striking the same sand where it is slightly less porous would obtain a smaller initial yield, but one much steadier and declining more slowly. In the good old days this difference explained the sporadic occurrence of spouting wells. Of recent years, when pumping is the inevitable rule, more and more attention has been paid to the question of extracting a larger percentage of the total content from an oil sand. More than once the writer has expressed the belief that the Yenangyaung field is one of the best run fields in the world. In recent years the field has been completely electrified, and there are now over 3,000 producing wells. Wasteful competition has been eliminated, but not friendly rivalry and a scope for ingenuity. About 1922 for several months one of the companies secured a goodly increase of production in its wells by the application of a little vacuum action. Probably the neighbours suffered infinitesimally, but conferences, followed by Government regulations, soon secured a uniformity of practice. A later development, at present increasingly favoured, is the forcing of gas under pressure down a disused hole and getting a distinctly increased production from the four or five surrounding wells.

It is interesting here to note also what a large proportion of the gas is recovered—a proportion rumoured to approach three-quarters. The discontinuity and varying character of individual oil sands have undoubtedly been the real reason for the long life of Yenangyaung. In the words of a well-known geologist, "the patient continues to bear up well, despite the treatment."

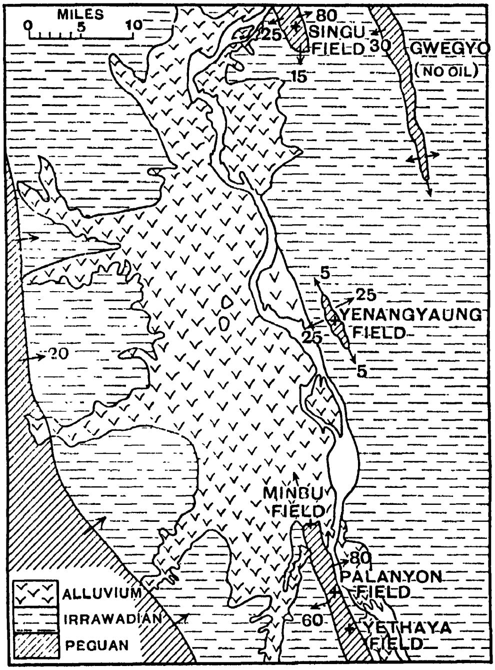

FIG. 7.—Sketch-map showing the large gathering ground of the Yenangyaung oilfield, and the relation of this field to its neighbours.

(c) In the third place, perhaps an aspect of the Yenangyaung field which is insufficiently stressed is the large extent of the gathering ground. This has been shown in Fig. 7, and serves at least to demonstrate the importance of lateral migration. As the writer has stressed elsewhere, it is doubtful whether *vertical* migration is anywhere important in Burma.

Production of Yenangyaung

	Native Wells (Gallons)	Drilled Wells (Gallons)
1888	2,548,171	17,468
1893	3,709,844	6,176,637
1898	5,550,119	8,238,708
1903	7,493,403	49,427,259
1908	7,950,376	115,687,120
1913	-	200,555,668 [1]
1918	-	203,638,043
1919	-	190,322,077
1920	-	176,285,048
1921	-	184,420,141
1922	-	179,741,493
1923	-	175,158,721
1924	-	181,636,739
1925	-	160,027,885
1926	-	145,731,612
1927	-	137,322,012
1928	-	135,969,794
1929	-	134,936,816
1930	-	132,893,282

6. Minbu.

The whole Minbu fold resembles the Singu-Yenangyat fold in that it is a long, asymmetric anticline of Peguan rocks with a north-south trend—about 20 miles in length. Along the fold are three oilfields—one, Minbu town or Minbu proper, is at the northern end and occupies a curious position some distance down the pitch; a second corresponds to a crest maximum near the village of Palanyôn; a third corresponds to another crest maximum south-west of the village of Yethaya.

In the description of Yenangyat two reasons were given for the increasing poverty of the Peguan when traced northwards. In the case of the Minbu fold there are three main reasons for its poverty when compared with Yenangyaung to the north. The first is the lithological change in the rocks—the marked increase in the proportion of clay laid down in deeper water and less suitable for the formation or retention of oil, a change still more marked in the Thayetmyo district farther south. The second is the same as that given in the case of Yenang-

[1] This figure represents the combined production of hand-dug and drilled wells from 1913 onwards.

yat: the greater thickness of Peguan exposed, and the fact that many of the higher petroliferous horizons have been denuded away. The third is the more intense folding—the rocks are frequently vertical and even overfolded on the eastern limb.

An account of the early exploration of the field, up to 1910, has been given by Pascoe and need not be repeated.

Taking now the first and most important of the three fields, the northernmost one, it is in many ways a geological anomaly. Just south of Minbu town the whole fold is crossed obliquely from south-west to north-east by a large fault, and along this fault the famous mud volcanoes of Minbu are situated. It is probable that the fault effectively seals off the northern end of the fold. North of it there is a domed structure (the Minbu dome) worked by the B.O.C. in Block 2N. The chief oil sands are at 450 to 750 feet—that is, they belong to horizons denuded away farther south. The Minbu dome pitches northwards at the steep angle of 12° to 15°, and one would think there were no further prospects northwards. Indeed it was not considered necessary to demarcate blocks north of Minbu town, nor did Pascoe map this area in detail. But a mile or two north of Minbu the northerly pitch changes from 12° to about 6°, and *this change in pitch has been sufficient to hold up an oil pool* on a sort of sloping terrace so formed. At the same time the crest of the fold is duplicated. The B.B.P. work the western half in Block 19P (about 20 shallow wells), the Y.O.C. the eastern half in Block 20P. The oil pool has an area of about 40 acres, and stretches into the northern end of the B.O.C. Block 2N, where the B.O.C. had about a dozen wells—all shallow and drilled with a light Leidecker machine about 1911-1912. Many of the shallow wells came in at 30-40 barrels; maintained 4 or 5 barrels for a long time, only gradually declining. To the best of the writer's knowledge several of the wells merrily yield a few tins of oil a day after a life of a dozen years. When the writer was living at Minbu in April-May 1922 the Y.O.C. wells were all linked up to one engine which pumped the lot at once for a couple of hours a day. The field is of great interest, not because of any large yield of oil, but because of the important effect of a slight change in pitch in effecting the holding-up of an oil pool.

7. Palanyôn.

South of Minbu the main fold rises steadily to a crest maximum or dome near Palanyôn. After extensive exploration in the various parts of the fold (see Pascoe's memoir) the B.O.C. located, and are still working, the Palanyôn structure. The oil is, of course, at a much lower horizon than that at Minbu town, and occurs at horizons probably 3,500–4,500 feet below the top of the Peguan.

8. Yethaya.

South of Palanyôn there are several slight crest maxima in the main fold, but a well-marked dome is developed towards the southern end. The field is worked by the B.O.C. and is named after a village some distance to the north-east.

Although Minbu town, Palanyôn and Yethaya are really entirely distinct fields they all lie in the Minbu district, and the productions are not separately stated in Government reports. When Sir Edwin Pascoe wrote his memoir in 1910 only small quantities of oil had been obtained, and production is first officially recorded for that year. The figures given below show that the three fields never have been large, and the production, after steadily declining, is showing a tendency to rise :

Production at Minbu, Palanyôn and Yethaya
(in gallons)

1910	18,320	1921	3,706,831
1911	632,458	1922	3,940,416
1912	3,896,365	1923	3,915,140
1913	3,198,311	1924	3,829,044
1914	1,683,190	1925	3,248,566
1915	2,316,207	1926	4,533,420
1916	2,043,542	1927	5,199,950
1917	3,468,382	1928	6,101,822
1918	4,826,735	1929	5,815,252
1919	4,423,361	1930	5,038,476
1920	3,835,198		

9. Tagaing or Minhla.

Immediately to the south of the Minbu fold of Peguan rocks is another fold of rocks of the same age which pitches sharply

to the north. It was on this northward pitching nose that the small field of Tagaing was developed, but it has never paid its way. Production reached a maximum of 113,784 gallons in 1919.

10. Padaukpin.

Southwards the Peguan rocks, as a whole, become more argillaceous and probably of deeper-water type. The highest beds are more mixed and capable of carrying oil, while much lower in the sequence are sandy groups, locally petroliferous.

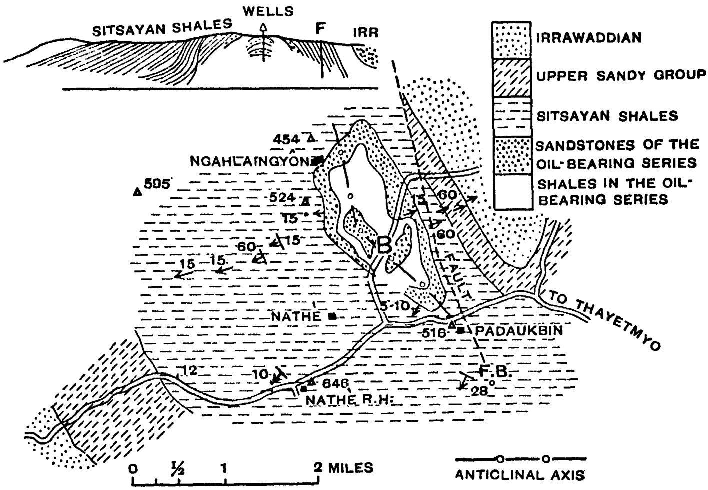

FIG. 8.—Geological sketch-map of the Padaukpin dome.

One of these lower sandy groups is exposed in the gentle, oval-shaped dome of Padaukpin. While the structure is good it is doubtful whether the petroliferous strata attain any considerable thickness. Since 1920 the field has been developed by the Indo-Burma Oilfields (1920) Ltd. Pumping started 7th March, 1922, and the production as recorded by the company averaged about 15,000 barrels from 1922-1926.[1]

The accompanying sketch map (Fig. 8) shows the nature of the fold and demonstrates the fact that although the structure is excellent, the beds are mainly of deeper-water type and the number of oil sands has been reduced to two or three.

[1] This is well-head production, and hence greater than the production (on which royalty is paid) shown in Government returns.

11. Yenanma.

Yenanma is a remarkable little field which stands alone among the Burmese fields. It seems, on superficial examination, to consist of a pocket of oil-bearing sands situated in the midst of a group of laminated clays and sands forming a homocline (or monocline) with a steady easterly dip of 20° to 25°. However, as explained by Murray Stuart,[1] it is believed by some that these beds are thrust westwards over folded rocks of similar or rather earlier age. Dr. Stuart considers that the oil pool lies actually in the fault plane, though the sections he has published show a hidden anticline lying below the fault plane. It should be mentioned, however, that this conception of the structure is not shared by many geologists who know Burma thoroughly well. Following along the outcrop, seepages may be traced for a distance of some 40 miles on two distinct horizons, one near the base of the Peguan and the other 2,000 or 3,000 feet lower, in the highest part of the Eocene. There may, therefore, be other oil pockets below the monocline, but there would seem to be no indication whereby they can be located. Yenanma is exploited by the Indo-Burma Oilfields (1920) Ltd. and the production, since the pumping was commenced, 12th January, 1922, has been as follows :

Production at Yenanma

	Barrels.[2]
1922	54,295
1923	36,649
1924	33,854
1925	27,000 (approximate)
1926	17,000 (estimated)

[1] *Journ. Inst. Petr. Techn.* vol. ii, No. 52, October 1925, pp. 481-85.

[2] Well-head production as recorded by the company. The Government returns for the Thayetmyo district, including both Padaukpin and Yenanma, as well as a few thousand gallons from Tagaing, are as follows :

	Gallons.		Gallons.
1922	2,319,835	1927	999,500
1923	1,818,584	1928	727,322
1924	1,717,653	1929	746,221
1925	1,320,009	1930	503,811
1926	974,620		

12. Arakan Coast.

Several of the closely folded anticlines of the Arakan coast are petroliferous, but the deposits appear to belong to a separate basin of sedimentation. The oil has been obtained mainly from two areas: Ramri Island in the Kyaukpyu district, and a small island south of Akyab in the Akyab district. The licensees of recent years have all been natives, and the oil is obtained by native methods; production is declining and has not for some years exceeded 50,000 gallons annually. In 1924 it was 21,714 gallons; in 1925, 21,530 gallons, being 7,169 gallons from the Akyab district and 14,361 from the Kyaukpyu district. No production was recorded from Akyab for 1931.

The Conditions of Deposition of the Oil-bearing Beds.

The rapid alternation of beds of impervious clay and porous sands almost precludes the possibility of extensive vertical migration of oil. Indeed, all the evidence which the writer has seen tends to support the view that the oil of Burma originated in the beds in which it is now found, and that only lateral migration has been important. All along the outcrop of the Yenanma and upper Eocene petroliferous horizons, little lens-shaped streaks—from $\frac{1}{8}$ inch to several feet in thickness—of sand saturated with oil may be found entirely surrounded by clay. It seems impossible that the oil could have got into such a position from outside. Similarly, in the great fields conditions are against vertical migration.

Presuming, then, that the oil originated where it is now found, certain definite conclusions may be stated:

1. Oil is never found in beds of definitely fresh-water or aeolian origin, such as the Irrawaddian.

2. Oil is never found in beds originating in deeper marine waters, "deeper" being here used in a strictly comparative sense. The Sitsayan shales—rubbly, or concretionary shales—are a typical example, but there are beds which, from their laminated nature, might be thought capable of bearing oil, but which do not. It has been found that these beds are characterised by what is sometimes called a "*Pleurotoma* fauna," which is generally acknowledged to indicate deeper water than certain

other mixed lamellibranch-gastropod faunas. The petroleum geologist is often apt to scoff at the use of fossils. The paleontologists are to blame to some extent for over-emphasising details of nomenclature. The oil geologist in Burma can learn a great deal of importance from the facies of an assemblage of fossils without knowing the name of a single one.

Oil is always found in strata in which the majority of the fossils are marine, but of shallow-water type. Traced along the strike into areas where the conditions more approached the fluvio-marine or fresh-water, the same beds in many places carry seams of coal. In all such cases oil is always found under more marine conditions than coal.

While, then, there is a very definite connection between the occurrence of oil and the conditions indicated by fossils, the lithology and tectonics, as in other parts of the world, have controlled the accumulation of large quantities. Lithologically, oil in Burma is found in beds characterised by a rapid alternation of sands and shales, whether on a very small scale (say in layers of $\frac{1}{8}$ inch) or on a large scale. Crystals of gypsum are common, but are more characteristic of beds above the oil horizons, and many of the localities where gypsum is most plentiful are non-petroliferous.

It has already been pointed out that during the deposition of the oil-bearing beds Central Burma was occupied by a gulf into which the fresh waters poured from the north. It is now possible to say that the oil-bearing rocks of Burma were deposited on the seaward side of a delta, and that the oil originated under such conditions of admixture of fresh and salt water as permitted the existence of a definitely marine, though shallow-water, fauna. Seaward (*Pleurotoma* shale facies) oil is not found; landward or riverward its place seems to be taken by coal; under definitely fluviatile conditions the vegetable remains have been silicified, and fossil wood is very common. Thus the evidence in Burma is that petroleum has originated from vegetable material, accumulated in sediments under brackish water conditions, and there acted upon by bacteria which have been responsible for the conversion of the material into oil.

Elsewhere the writer has made a detailed study of the banded

sediments in which the oil sands occur. It is considered that the banding is due to the annual flooding of the old Tertiary rivers which embouched into the Burmese Gulf, and that each double lamina of coarse and fine sediment represents the deposits of a single year. On this assumption the writer has calculated that the Peguan period (Oligocene—lower Miocene) lasted about 2,250,000 years. The laminae of these " varved " sediments extend from $\frac{1}{20}$ inch upward. For further details reference should be made to an earlier paper[1] by the writer.

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CHAPTER X

TIN DEPOSITS.

THE chief tin-producing areas of Burma form a northern continuation of the mineralised region extending from Bauka and Billiton Islands in the Dutch East Indies, through Malaya, Western Siam to the Mergui, Tavoy, Amherst, and Thaton districts and the Karenni Hills of Burma.

The two minerals, cassiterite and wolfram, are usually associated, and mixed concentrates are obtained in most localities. In some areas the proportion of wolfram is greater than that of tin, and such are treated as wolfram-producing localities; while on the other hand, on account of the partial or complete removal of wolfram by disintegration or decomposition the major portion of the concentrate from the alluvial deposits is tin-ore. Such areas are referred to as tin mines. During the years 1888 to 1892 a systematic exploration of the tin deposits of the Tavoy and Mergui districts was carried out by a party of prospectors under the superintendence of T. W. H. Hughes, the results of which were published in *Rec. Geol. Surv. Ind.* vol. xxii, 1889, pp. 188–208. Later investigations of the deposits in Lower Burma were undertaken by J. J. A. Page during the years 1907 to 1912, and abstracts of his work have appeared in *Rec. Geol. Surv. Ind.* vol. xxxvii, 1908, pp. 1–56, and vol. xxxviii, 1909, pp. 1–70. The Tavoy district was investigated in great detail, and a memoir on its geology and mineral deposits was published by Coggin Brown and Heron.[1] In 1930 Sethu Rama Rao[2] published an account of the geology of the Mergui district, and in this the tin and tungsten deposits are described.

[1] *Mem. Geol. Surv. Ind.* vol. xliv, 1923, pp. 167-210.
[2] *Ibid.* vol. l, 1930.

IMPORTANT ORES OF TIN FOUND IN BURMA.

Of all the tin-bearing minerals the most important is cassiterite or "tinstone," the dioxide of tin containing 78·6 per cent. of the metal. In Burma it occurs in a variety of forms and colours, and it is obtained in masses as well as in isolated crystals. Sometimes it exhibits a woody structure, and then it is known as "wood tin." Though the mineral most commonly is either black or brown, still white, grey, pink and chocolate coloured cassiterite has been discovered in different localities in Burma. It has a splendent or adamantine lustre, it breaks with a conchoidal fracture and generally occurs in small crystals, though ideally perfect forms are not abundant. It has a hardness of 6–7 in Moh's scale and a specific gravity of 6·8–7·1. Although the above-mentioned properties should enable anyone to distinguish this mineral from wolfram, with which it is so intimately associated in Burma, yet the practical difficulties are many and the only reliable means of identifying cassiterite or any other tin ore, where there is any doubt, is to examine it with the aid of the blow-pipe. It is infusible, and shining globules of tin can be obtained when it is reduced on charcoal with sodium carbonate.

MODE OF OCCURRENCE.

The tin and tungsten ores are generally found in or near the outer margins of granite intrusions, in pegmatite and greisen veins, as segregations in the granites and in quartz veins penetrating them and the adjoining sedimentary rocks. Tin ore is also obtained from placer deposits and is recovered from detrital or eluvial deposits. The last two form the most important resources of ore at the present day.

When the deposit occurs in the form of lodes the cassiterite is almost always associated with wolfram, though cassiterite-free wolfram deposits are common. In the Tavoy district only one instance is known of a cassiterite-quartz vein containing no wolfram. In certain zones the percentage of tin ore becomes sufficiently high to justify the term "tin deposit," and the proportion of cassiterite in the mixed concentrates may rise as high as 25 per cent. This is notably the case where the lode is

found cutting through granite rather than through sedimentary rocks, though exceptions to this rule are known. More especially, cassiterite is found in greater quantities in greisens. The common minerals that are associated with cassiterite are wolfram, sulphides of iron, copper, molybdenum, lead, bismuth or zinc, and of these the sulphide of iron is generally predominant. Small quantities of fluorspar are occasionally obtained. The mineral association in order of deposition, according to J. Coggin Brown, is as follows : molybdenite, wolfram, cassiterite, native bismuth, bismuthinite, chalcopyrite, arsenopyrite, pyrrhotite, galena and blende.

Detrital Deposits.—A great proportion of the mixed concentrates of wolfram and cassiterite is obtained from true detrital deposits. In the Tenasserim division the rainfall is very heavy, consequently during the rainy season outcrops of the tin ores which occur on the hill slopes are denuded and the material washed into the channels of surface drainage. In this manner true eluvial deposits are formed along the channels of the main streams. The concentration, as is naturally to be expected, is greater as the parent lode is approached. The factors which govern the percentage of cassiterite present in such detrital deposits are : first, the amount of cassiterite present in the neighbouring lode ; and, secondly, the distance of the deposits from the parent lode. Stones and boulders are very common in these eluvial deposits and often make up a large percentage of the total.

Placer Deposits.—As a result of denudation, tin-bearing lodes which crop out at the surface are broken up and the material carried down hill until it rests finally with the alluvial deposits in the valleys. Of this kind of deposit the richest appear to be the " placers " of the lake bottoms. Dredging operations performed in some of the lakes of the Mergui district have revealed the presence of concentrated ores at the bottom. This is explained by the considerable changes in the topography of the area that took place during Recent times, as a result of which there appears to have been a general lowering of the interior and the former sites of river valleys are now occupied by lakes. It is noteworthy that wolfram is seldom found in true placer deposits. In those rare cases in which wolfram is

observed in placers, it occurs tightly enclosed in unfractured quartz, to which it owes its preservation. Chemical analysis of the tin ore obtained by dredging in Tavoy reveals, as a rule, less than 0·25 per cent. of WO_3, though the detrital deposits of the slopes, from which the placers are derived, would probably show more wolfram than cassiterite. The reason is that wolframite possesses a very perfect cleavage, which brings about its rapid comminution on movement, and then it is easily carried away in solution by the surface waters acting upon it. Molybdenite is also similarly affected.

Recent Deposits.—Recent deposits in the Tavoy district include the modern alluvium of the paddy plains, the islands of tidal rivers and the swamps along their banks, the modern laterites and lithomarges, and the sands of a rapidly falling coast. In some of the smaller valleys the modern alluvium is being derived partly from a re-assortment of the older deposits.

Sub-Recent and Late Tertiary Deposits.—The Sub-Recent or Late Tertiary Deposits are of great importance, for they are likely to contain rich cassiterite placers. They occur as river terraces above the present level of the inland streams, such as the Pauktaing at Thingandon. They also occur at Maungmeshaung, where they yield good values, and in the Kalonta, Heinze and Zimba *chaungs*. They also occur as lacustrine and fluvio-lacustrine deposits laid down in the still waters of the Myitta and other lakes ; as deep eluvio-alluvial beds in the submerged basin of Kanbauk and other places ; as clay banks containing the remains of marine animals and now found raised above sea-level in the vicinity of the Tavoy estuary.

The country has undergone secular changes of depression, evidenced in the coastline and interior, followed by upheaval. The deposits of the Myitta valley must have been laid down under fluvio-lacustrine conditions. The changes in the level of the land intercepted the drainage of the main branches of the Upper Tenasserim river, the Kamaungthwe and Ban *chaung*—the flow of these streams was prevented and large sheets of water must have slowly accumulated. Deposition became the rule, where erosion is taking place to-day. The lakes, therefore, became rapidly filled in with material washed down by innumerable streams from the steep slopes surrounding them.

Some of these streams drain granitic country and cross the contact of the granite with the Mergui sedimentary rocks. Mineral-bearing veins yielded their metallic contents ; the wolfram and molybdenite were dissolved and lost ; the resistant cassiterite was carried down and deposited in the sands and gravels at the margins of the lakes. To-day the streams are cutting into the older deposits owing to more recent uplift. The Myitta lake is typical of others, though it seems to have been the largest one of its kind. Similar conditions prevailed in the valley of Zimba and other tributaries of the Tavoy river.

MERGUI DISTRICT.

Mode of Occurrence.—The tin mines of the Mergui district lie mostly on the mainland, where two parallel mineralised zones may be distinguished, and along which most of the working mines occur. The tin ore mined is entirely cassiterite, which is associated with granite and is found in close proximity to the granite bosses, at and near their junction with the sedimentary rocks of the Mergui Series. It is noteworthy that whereas tourmaline is absent from, or very rare in, the lodes in the Tavoy district, it is a common mineral in the lodes of this district. The other associated minerals are common to both districts. In the islands of the archipelago another belt containing mainly tin is now being worked in the Lampi (Sullivan) and adjoining islands. On the western slopes of the eastern range of granite forming the Siamese boundary some occurrences have been reported, but no details are known. The country is sparsely populated and would present difficulties in the way of transport and labour.

Sethu Rama Rao reports that tin occurs in this district in the following forms :

As original constituents.

(1) In quartz veins and stringers traversing the granite and sedimentaries ; sometimes in massive quartz segregations in and on the outskirts of granite hills ;

(2) in decomposed pegmatites containing muscovite and tourmaline ; and

(3) as segregations in greisens ;

As detrital material.
(4) in talus (eluvial) deposits on the slopes of hills near the outcrops of (1), (2) and (3) ;
(5) in stream deposits and alluvial flats bordering streams which rise in mineralised zones ; and
(6) in deposits along the lower courses of the rivers.

Quartz veins (1) occur at the margins of granite and range up to nine or ten feet in width. Cassiterite is associated with sulphides of other metals which are chiefly pyrites, chalcopyrite, arsenopyrite, molybdenite, stibnite, and bismuth. This mode of occurrence has been noticed at the North Hill, Khow Maung, and Peetolai mines, of the Maliwun area ; the Thitlat mine of the Tagu area ; the Hkyekhat *taung* of the Pyicha *chaung* area, and the mines in the Santhe *chaung* area. Sometimes narrow quartz veins and quartz stringers form stockworks in the rocks of the Mergui Series, for example in the Tuthwe area, Lampi and the adjoining islands, the Hangapru area, portions of the Palauk area, and parts of the Palawpya area.

The examples of decomposed pegmatites (2) and greisens (3 in the above list) containing tourmaline and muscovite and formed at the margins of granite are represented by the following areas : Palaw river source, Yamon, Manoron area, Yengan, Migyaung, Inner Bokpyin, Yanngwa, Kyaukkyi, Banhuni, and Nam Noi.

Sethu Rama Rao classified the localities where tin and wolfram ores are worked on the mainland, according to their geographical position and with reference to the different ranges of granite and mineralised zones, as follows :

A. **The Northern Group.**—*Palauk township*—Wolfram and tin.—Shauk *chaung*, Kauko Aing, Mwechaung *chaung*, Baukadun *chaung*, Gyaw *chaung*, Naku *chaung*, Saku (Kathe) *chaung*, Kathadok *chaung*, Legataung, Hkyekhat *taung*.

This township is on the west coast in the north of the district. The mines listed above are worked at intervals in spite of very great transport difficulties. The tinstone occurs in narrow quartz veins trending east to west and some north-east to south-west and traversing schists and phyllites near the granite

margin. Molybdenite occurs in small quantities in some of the veins.

Palaw township—Tin only.—Shanthe *chaung*, Palawgon, Palawapya, Madaw and Kyaukpyu, Zadiwin, Migyaungthaik *chaung*.

B. **The Central Group.**—*Mergui township*—Tin only.—Yamon, Kahan, Mayinhla.

Tenasserim township—Tagu, wolfram and tin. Thabawleik and Theindaw, tin only.

C. **The Southern Group.**—*Bokpyin township*—Tin only.—Bokpyin river valley, Yaungwa, Hangapru, Yengan, Sadein, Migyaung *chaung*.

Bokpyin township—Tin only.—Manoron *chaung*, Khe *chaung*, Hosankhu *chaung*, Ahnyinzon *chaung*, Kyauk-kon Island and Lundaung, Karathuri, Kyaukkyi *chaung*.

Victoria Point sub-division—Tin.—Klong Banhuni, Klong Yung, Klong Lam Noi pre-sai, Klong Lama and Klong Saden. Wolfram and tin.—Maliwun.

In the Mergui Archipelago the islands in which tin ores are mined on a commercial scale are (1) Pà Pula Besin (Long Island), (2) Pulo Bada (Sir James Island), (3) Pulo Lampi (Sullivan Island), and others situated along this line. Tin ore is also found in Kisseraing Island. Coarse stream tin occurs in the courses of the Ngawun, Theinku *chaungs* and their tributaries.

Though tin lodes occur in the Mergui district, lode mining is not general. During the War, when wolfram commanded a high price, many mines were worked for wolfram alone, but after 1918 the mines were closed. Only detrital and alluvial deposits rich in tin ore are now worked. The ore obtained by working the veins and lodes occurs in large pieces, individual masses of many inches in diameter being obtained, while the concentrates obtained by sluicing the decomposed rock slopes and the detrital deposits are less coarse in texture. In the upper parts of the streams close to the parent lodes coarse grains of the size of a pea can be obtained ; while farther down stream alluvial deposits yield a concentrate of finer grain.

Future Prospects of the Tin-Mining Industry.—Although many new areas have been opened up, and the output of tin ore during

the last twenty-five years has been considerably increased, yet there are many areas that deserve prospecting. Heavy rainfall, extending over six months, thick vegetation and inadequate means of communication are the chief obstacles in the way of exploring the country. Nevertheless, the district holds out great promise for the future, and, in the opinion of Sethu Rama Rao, the belt of country extending from Klong Nam Noi northwards to Kadin, near the source of the Kyaukphon *chaung*, has not yet been properly tested on account of its inaccessibility. The alluvial flats north of Baukachon on the Maliwun road are virgin lands worth attention. The junction of the granite with the sedimentary rocks has been tested casually but not worked at the following localities, that Sethu Rama Rao recommends for further attention: Klong Lama, Klong Hassai Deng, Klong Nam Noi, Klong Ply Ngon, the source of the Karathuri *chaung*, the islands west of Karathuri, and Kyatme.

TAVOY DISTRICT.

History of Tin Mining.—The date of the beginning of tin mining in Tavoy is lost in obscurity; but judging from the ancient workings it must have been carried on for a very long time. That tin mining must have been in full swing even some three centuries back is seen from the following authentic report by Ralph Fitch in 1599: "I went from Pegu to Malacca passing seaports of Pegu, as Martauan (Martaban) the island of Taui (Tavoy) from whence cometh great store of tinne, which serveth all India." As early as 1836 Captain Low published a list of tin mines and stated that they provided employment for 400 Burmese during four months in the year. In 1839 Dr. Helfer published the results of his travels in Ye, Tavoy and Mergui. In 1849 O'Riley published a communication dealing with the metalliferous deposits of Tenasserim in which a list of tin mines is given, including the Taungbyauk *chaung*, the head-waters of the Tenasserim and the stream flowing into the Heinze Basin. Mason wrote in 1882: "No tin has been raised since the country came into our possession; but it was worked during Burmese rule and valued as supplying the richest ore of tin. At Kaymatphoo east of Toungoo and on the eastern slopes of Papoung-

long range a few miles beyond the British boundary tin is largely worked by Karenni or red Karens who cast the metal into small pegs each of which circulates as rupees." Again, Coggin Brown wrote: "It is possible that the indigenous tin mining was almost extinguished during Alompra's invasion in the middle of the eighteenth century . . . and extensive tracts of a very fertile district were depopulated to an extent which has not been made up since." In 1905 the Golden Stream Syndicate was formed, and this concern had prospecting rights over an area of 350 square miles, including most of Paungdaw and the Upper Kamaungthwe valley, but the venture resulted in failure. Even as late as 1908 there was little or no output of tin: J. J. A. Page records the output for 1908 as barely one ton. The tin industry in Burma received an impetus when there came a demand for wolfram, and at first more attention was paid to the latter; during the Great War large quantities of this mineral were required and new mines were therefore opened. But after the War the demand for wolfram slackened and concentrates of tin are being mainly worked at the present day.

Geological conditions in the Tavoy district are almost the same as those described above for the Mergui district. Though the Tavoy district is primarily a wolfram-bearing region, yet there are areas within its confines which are very rich in tin.

Mines.—The best method of grouping the mines in this district is with the granite masses with which they are associated. Commencing with the Coastal Range the mines are Kambay, Kanbauk, and Pachaung, etc. In the Central Range are the Taungpila, Wagon, Putletto, and Widnes mines. The Zimba mine is situated in the Frontier Range.

The **Kambay** mine produces chiefly wolfram and practically no cassiterite.

At **Kanbauk** a number of veins occur in the Mergui Series, traversed by a thick basic dyke, a little to the east of the main lode series. The lodes are often drusy, which is an unusual phenomenon in the Tavoy district. In this neighbourhood extensive alluvial and detrital deposits yield cassiterite, wolfram and oxidised bismuth compounds in profitable quantities. The mixed concentrates, however, especially from the alluvial

deposits (when wolframite has disappeared in solution in percolating waters), carry a relatively high percentage of cassiterite. The mixed concentrates are sent to Tavoy to be separated electro-magnetically and the cleaned tinstone concentrates are shipped to Penang.

Pachaung.—The mines of Pachaung and those of Kechaung are mainly wolfram-producing.

Byaukchaung and Kalonta.—The groups of these mines in the Bolintaung-Byaukchaung range contain little cassiterite, though the latter yields more than the former.

Pagaye is in the Kyaukanya-Peneichaung range, due south of the Kalonta mines, and is within about ten miles of Tavoy town. A number of wolfram-bearing pegmatites carrying a little cassiterite occur. During 1916–1918 this mine produced between ten and twenty tons a month of mixed concentrates, carrying varying quantities of tinstone, sometimes up to ten per cent.

Hermingyi lies just north of the Central Range. Veins occur both in the granite and in the sediments, while detrital deposits occur on the slopes of the Tin Hill and Big Hill. Wolfram and cassiterite occur in payable quantities, and the mixed concentrates carry, on average, about 20 per cent. of tin. The bulk of the output has been obtained from narrow quartz veins, from 8 to 14 inches wide, trending north to south and traversing the schists and phyllites. The latter have been much decomposed to considerable depths ; thus the quartz veins outcropping on the hill slopes are followed easily. The lode material is broken up by hand-hammers and the wolframite and cassiterite concentrated in small sluice boxes.

Taungpila mine adjoins the Hermingyi mine and is one of the six largest producers of wolframite-tinstone concentrates in the Tavoy district. The mode of occurrence is similar to that observed in the Hermingyi mine.

The **Wagon** area lies a little to the south of Taungpila. The amount of cassiterite is very small, and chlorite, molybdenite, wolfram and fluorite occur.

At **Widnes** all the workings are extensive, some sections showing seventeen veins. The cassiterite content is very small, however.

Meke is a few miles south of the Central Range. Tin occurs in the Nanpayok and Yange areas.

The **Zimba** mine occurs in the Frontier Range, and several lodes are found in the granite near its contact with the Mergui Series. The concentrate, however, contains very little tin.

Here the ore occurs both as lodes in the granite and also as alluvial and placer deposits. The greater portion of the Tavoy coast is composed of granite, which in places is traversed by important rivers, and along the coast there are several cassiterite-bearing localities. Placer deposits carrying cassiterite occur in the alluvium of the Heinze basin (14° 45′, 98° 0′), where the Northern Tavoy Tin Dredging Company Limited have two dredgers working. In the Hindu *chaung*, about 16 miles due east-north-east of Tavoy town, three dredgers belonging to the Tavoy Tin Dredging Corporation are at work ; while the Shwe *chaung* concession has been proved to contain reserves of ore-bearing ground. The tinstone is found in alluvial deposits consisting of well-rounded pebbles and sand, free or almost free from clay, making it a very easy dredging ground both for digging and treatment in the sluice boxes. The deposits are from 20 to 25 feet thick, the richest being the bottom few inches. The concentrates carry tinstone, topaz, a little monazite and gold, but no wolframite. The placer deposits are also found in the Kalonta stream (14° 19′, 98° 19′), the Zinbei stream (14° 38′, 98° 10′) and Maungmeshaung *chaung* (14° 19′, 98° 13′). At the last locality the Kamounghla Tavoy Tin Company works certain deposits. The country near Ohnbinkwin (14° 37′, 98° 0′) in the Heinze stream is also worked. The Thingandon Tin Dredging Company Limited has a dredger operating on an alluvial flat on the Pauktaing river, 18 miles north-east of Tavoy town. Alluvial tin occurs near Sinthe (14° 16′, 98° 12′) and 22 tons of ore were produced in 1918.

AMHERST DISTRICT.

The output of tin ore from the Amherst district is negligible and only averaged 2·9 tons per annum for the quinquennium 1924–1928. The metamorphic aureoles around the granites of the district have been proved to carry tourmaline and veins

of tourmaline-micropegmatite, which in places bear quartz stringers containing cassiterite. The lateritic talus deposits at Thetkaw and Sakangyi have been worked sporadically. Eluvial and alluvial cassiterite are found in the Belugyun Island at the mouth of the Salween river on the lower slopes of the ridges of argillaceous quartzites and slates which form the backbone of the island. The cassiterite is most probably derived from veins of granite-pegmatite and quartz, which are here intrusive into metamorphosed sedimentaries and which are known to carry tourmaline. To the west and east respectively of the Seludaung ranges some eluvial and alluvial tin has also been won. Black cassiterite occurs in a small pegmatite vein at Kunhnitkway (15° 48′ 22″, 97° 51′ 36″) in the Amherst district.[1] The maximum thickness of the vein is two feet and it follows the bedding planes of the country-rock, here consisting of sandy shale and sandstone. The strike is north 38° west–south 38° east and the vein dips westwards at 70°. It thins out in places but reappears farther on in the same line. The pegmatite is much kaolinised, and the extraction of cassiterite, in which the rock is rich, is not difficult and is carried on during the monsoon. However, the vein being narrow and the dip steep, it will perhaps be soon unprofitable to work it on account of the increasing overburden. No attempt has been made to ascertain if the talus on the slopes below the vein contains a payable quantity of ore.

The tin mined around Mawpalawtaung (15° 52′, 97° 46′), east of Karokpi, in the Amherst district, occurs in the lateritic eluvial deposits at the foot of the hill which is built of sandstone and banded quartzite associated with shales and micaceous slate. The ore, which is chiefly grey cassiterite, appears to be derived from small quartz stringers intruded into the sandstones during the granitic intrusions in the province.

THATON DISTRICT.

In the Thaton district cassiterite is found mainly in the central ranges and at the extreme margins of the wolframite-bearing area. The ore is found in the granite, with tourmaline

[1] *Rec. Geol. Surv. Ind.* vol. lxiii, 1930, p. 55.

as an important accessory. The lodes occur in the pegmatite veins in the granite. In all there are four lodes, which are remarkable for their regularity in width (averaging 4 inches) and continuity: some have been traced for a distance of two and a half miles.

Alluvial tin is worked near Kadeik, about 10 miles north-north-west of Thaton. Another concession occurs south of Zingyeik railway station, 16 miles south-south-east of Thaton. The output from this district, however, is very small and averaged only 7 tons per annum during the years 1924–1928.

Mawchi Mines, Karenni.—The mines are situated in the sub-State of Bawlake at Kehdaung (Tin Hill) at a height of 3,000 to 4,000 feet above sea-level near Mawchi on the Ke-ma-byu river, a tributary of the Salween. The existence of tin in this locality has been long known; but O'Riley[1] was the first European to visit it and to give an authentic account. In 1910 the mines were visited by J. J. A. Page.[2] There are at least ten important lodes, varying from two and a half to five feet in thickness. The general strike is north-north-east to south-south-west and the dip either vertical or at high angles to the north-north-east. All the lodes are in granite, and the capping of the granite hill in which they occur is composed of limestones. The vein stuff in all the lodes is cassiterite, arsenical pyrites, chalcopyrite and, in places, tourmaline. Cassiterite and wolfram occur as intimate mixtures and also separately. The concentrates are recovered by an up-to-date mill. During the Great War, when wolframite was much in demand, this mine was very active, producing between 20 and 50 tons a month of mixed concentrates carrying almost equal proportions of tin and tungsten minerals. But in 1919, when the price of wolframite dropped by 40 per cent., the mine was temporarily closed down. However, towards the end of 1928 a complete reorganisation of the mine was effected, and at the same time a programme of development was initiated by driving two main low-level crosscut adits, the first of which has already intersected all the lodes in the western section of the hill. It is anticipated that, with the resumption of milling activities at

[1] *Journ. Roy. Geog. Soc.* vol. xxxii, 1862, p. 208.
[2] *Rec. Geol. Surv. Ind.* vol. xli, 1911, 47-pp. 85.

Mawchi, the output of both wolfram and tinstone from this region will be fairly good.

ORIGIN OF THE CASSITERITE AND WOLFRAM.

At least three theories have been put forward to explain the origin of the ores of tin and tungsten. A. W. G. Bleeck is of the opinion that tin-bearing solutions from deep positions in the earth deposited their metallic contents in cracks in the consolidated granite. His views, however, have not been accepted entirely by later workers. J. Coggin Brown and A. M. Heron believe that the mineralisation was due partly to the differentiation of the granite magma and partly to the action of hydrothermal and pneumatolytic agents. W. R. Jones supports the pneumatolytic theory of the origin of the deposits. According to Morrow Campbell the ore formation is largely due to the work of highly siliceous solutions, which leached tin and tungsten from the magma and at quite moderate temperature deposited cassiterite, wolfram and associated minerals in veins. After a careful consideration of the above theories and also the evidence in the field, Coggin Brown and A. M. Heron have put forward the view that the wolfram, cassiterite and sulphide deposits of the Tavoy district were formed partially under conditions closely allied to strictly magmatic ones ; but also to a certain extent by pneumatolytic processes, and in rarer cases by hydrothermal reactions which followed. They have suggested that the place of the customary fluorine and boron may have been taken by sulphur and arsenic in the pneumatolytic stages of ore formation here. This conclusion was based on the universal presence of sulphides, generally in the form of pyrites in the Tavoyan lodes, and the relative absence of minerals containing fluorine and boron.

Some of the lodes in the Tavoy district are pegmatites, which contain felspar as well as quartz. They have the composition, structure, texture and other characteristic features of normal pegmatites, but they carry wolfram and cassiterite in addition to their normal constituents. Cases where pegmatitic origin is not so clear may represent a hydrothermal phase of pegmatite development resulting in the production of quartz with the

ore minerals. Instances are known where true wolfram- and cassiterite-bearing pegmatites merge, in short distances along their strike, into pure quartz veins carrying wolfram and cassiterite. The presence of greisens, which sometimes border the walls of lodes in granite and also carry valuable quantities of ore minerals, cannot be explained by any theory other than the pneumatolytic one ; but it is not certain whether fluorine and boron played an important rôle in the reactions. It is impossible, however, to draw any hard and fast line between the different stages, which are all parts of one continuous process, doubtless proceeding concurrently in some cases. In fact, the whole formation of mineral veins associated with the granites, extending from the southernmost limits of Burma to an unknown termination in the Southern Shan States, as far as known at present, appears to be a direct sequence of deposition or fractional crystallisation through a series of varying phases, induced in the original granitic magma by decreasing temperature.

All the wolfram and cassiterite occurrences in Burma, however, are not identical. Tourmaline is present in the Mergui lodes and also in those of the Thaton district. Beryl is a common mineral in the lodes of the Yamethin district.

W. R. Jones has classified the tin and tungsten deposits of the world according to their mode of occurrence into the following classes : (1) Segregation deposits ; (2) Contact metamorphic deposits ; (3) Pegmatoid deposits ; (4) Quartz-vein deposits ; and (5) Replacement deposits. J. Coggin Brown has questioned the soundness of this classification, for it tends to obscure the fundamental and very close relationship between them all, this being due to the fact that they came into existence as a succession of phases induced in siliceous granite magma by decreasing temperature. W. R. Jones has adduced evidence to show that (1) the segregation and (2) contact metamorphic deposits were formed at higher temperatures than were (3) the pegmatoid deposits ; that the latter were formed at higher temperatures than (4) the quartz vein deposits. Furthermore, the deposits in which cassiterite and wolframite occur in intimate association were formed in a lower temperature zone than were the bulk of the tin deposits free from wolframite, and

PLATE VII.

FIG. 1.- TIN MINING BY SLUICING.

Notice the stream of water being brought by the high-level flume (on right) and the water being directed down the face of the excavation. Workers below are taking out baskets of partly-washed concentrates.

FIG. 2. BURMESE WOMEN PANNING TIN AND WOLFRAM, TAVOY.

cassiterite is a higher temperature mineral than wolframite. Assuming that the two hypotheses are correct, it is suggested that some of the deposits of the Tavoy district, where cassiterite and wolframite occur in intimate association, will be found in depth to resemble the tin deposits of parts of Siam, Malaya and Cornwall in England. The presence of tourmaline is an index of high temperature of formation, and in general this mineral does not occur in deposits where wolframite predominates over cassiterite. But these hypotheses also have been challenged by J. Coggin Brown, who states that "specimens have been collected which show that in some lodes tin mineral was the first to be deposited, the tungsten compound coming second ; but this is very rare, in most examples tin has clearly followed tungsten." He is convinced that, in the great majority of cases, the wolfram is older than the tin ore.

METHODS OF MINING.

The veins are worked by open-cast and underground methods, and practically the whole of the concentrates are recovered by the wasteful processes of cobbing and panning. It is impossible to separate wolfram from cassiterite by mechanical means, and until recently the mixed concentrates were shipped as such. But now an electro-magnetic separator has been installed in Tavoy, and the tinstone and wolframite are separated before shipment.

In other cases where the deposit is found on the surface itself hydraulic methods are employed for obtaining the ore. In the early days of the industry a great part of the ore was won by ground-sluicing rich patches of detrital or eluvial deposits on the slopes of hills when water was available during the rainy season (see Plate VII, Fig. 1). Not until 1912 did miners come to realise that detrital deposits could be very profitably worked by monitors and hydraulic appliances. Nowadays hydraulic sluicing methods are employed on a large scale. Water is pumped sometimes even to a height of 200 feet from the water-surface and stored in miniature reservoirs, which, when full, are suddenly emptied. The water is allowed to run down the hill side through sluices, where the ore is caught.

In one particularly rich mine, however, where it is not expedient to break down the boulders by hydraulic pressure, the gravels are washed and panned for the recovery of the ore. The tin deposits of the Hindu *chaung* valley in the Tavoy district were at first extracted by dredging, with the result that dredgers, that were formerly used in dredging gold from the Irrawaddy in the Myitkyina district, are now being used for the winning of tin deposits. Further, bucket dredging has become an established industry in Tavoy, and it is expected that this method will be adopted on a larger scale very soon (see Plate VIII).

Tin mining in the Mergui district dates back to remote times. The working of the alluvial flats at the foot of the hills and in the banks and beds of streams for the collection of tin concentrates has been carried on since the eighteenth century, mostly in the southern part of the district near Bokpyin, Karathuri and Maliwun, even at times when the price of tin was low. The local residents accomplished the necessary preliminaries for *taungya* cultivation during the dry months, and during the rains they sluiced the alluvial deposits along the chief streams.

The primitive method of washing the pay-dirt in the sluice boxes is still practised by Siamese and Chinese miners, who divert a small stream on to the surface slopes of a hill, the weathered rock being removed by the force of the torrent. The lighter material is washed away while the heavy residue is collected at the foot of the sluice in long sluice boxes. This impure concentrate is again cleaned in smaller sluice boxes by flowing water. The Chinese method of working the alluvial deposits in a flat country is by open quarrying styled the "*zampan.*" First, trial pits are sunk to estimate the thicknesses of the overburden, tin-bearing gravel and pay-dirt. The overburden is removed by digging pits about 10 feet square to varying depths, and afterwards the gravel and soil containing the tin ore are removed from the bottom to a place where water is available for sluicing. In time a series of pits coalesce and a large open quarry is formed. Water from the pits is baled out by buckets attached to water-lifts.

The concentrates are either smelted locally or exported direct to Singapore.

PLATE VIII.

A VIEW OF THE INSIDE OF A TIN DREDGER.

The tin-bearing gravel is thoroughly mixed with water in the drum on the right, and the mixture is then run out into inclined channels. Here it is raked by the men seen in the photo on the left, and the heavy tin ore is left as a concentrate, the lighter gravel being washed away.

TIN SMELTING.

The major portion of the tin ore is exported to other countries, chiefly to Malaya and the Straits Settlements. In earlier days the tin ore was smelted locally by the Chinese method and the metal was exported as block tin. Even to-day the most modern types of furnace have not yet been introduced into the district.

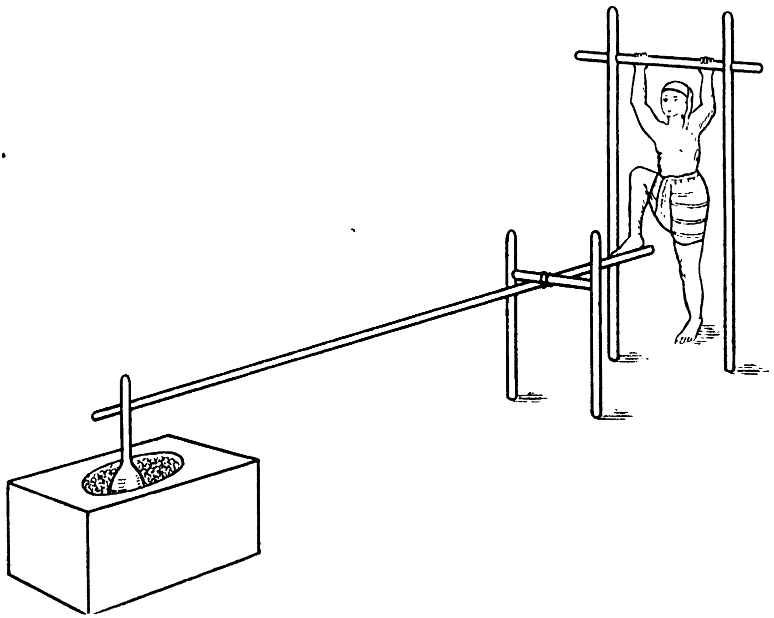

FIG. 9.—A native crusher for crushing tin ore as used in the Mergui district.

There are several local smelting centres. In the neighbourhood of Mergui, as observed by the author, the ore, after washing and dressing, is pounded in a crusher of native design, shown in Fig. 9. It consists of a stone mortar in which the ore is placed, and the crushing is done by an iron hammer worked by manual labour on the principle of a lever. The furnace is barrel-shaped, and is made of mud to which some common salt has been added (see Fig. 10). It is fastened by both vertical and horizontal iron bands, about one inch wide, and stands on three legs, about one and a half to two feet from the ground. It is placed in an inclined position and has two openings at the

bottom, one in front and the other at the back. The former serves as an exit for molten matter by gravity, and the latter is connected by an earthenware pipe about two inches in diameter to a horizontal cylindrical wooden bellows to admit a blast of air into the furnace. The bellows is a cylindrical hollow tree, about one foot in diameter and ten feet long, fixed on the ground at a low inclination so that a man can work the wooden piston standing.

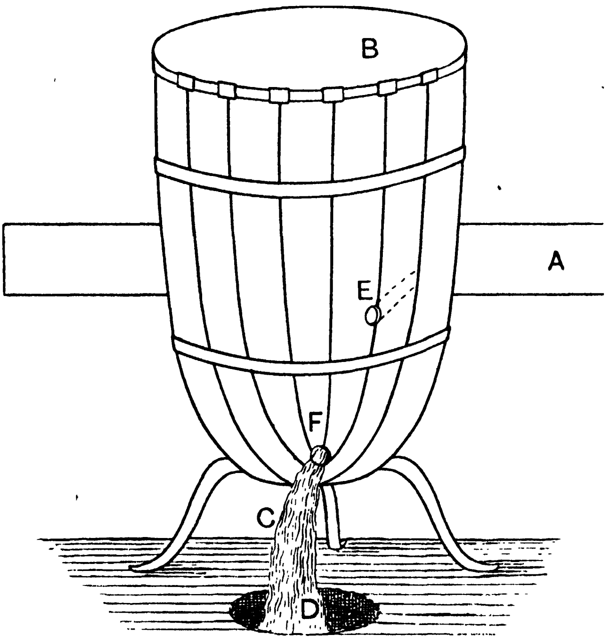

FIG 10.—Furnace for smelting tin. *A* are the bellows and *E* is the hole through which the air enters the furnace. *F* represents the opening through which the smelted ore *C* comes out. *D* is the receptacle for molten tin and slag.

The furnace is charged with tin ore, between two layers of charcoal of good quality. The molten matter is received in a wrought-iron cup, covered with burning charcoal. It is about six inches deep and eighteen inches in diameter, and is fixed in a hollow in the ground. The slag floats on the metal and is removed by a ladle. The molten matter is then ladled from the iron cup into specially prepared moulds by an iron spoon with a long handle. The tin from these moulds is refined in an

ordinary fire and cast into ingots for dispatch. There is much waste and the metal is not fully extracted during the first smelting. The slag is therefore remelted three or four times to make a thorough extraction of the metal. In the town of Mergui and elsewhere the author saw extensive old tin slags, indicating that the smelting industry in the past must have been carried on on a fairly large scale, although the date of commencement of smelting tin in the Mergui district could not be ascertained.

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CHAPTER XI

TUNGSTEN DEPOSITS.

Wolfram Belt.—As noted above, the ores of tin and tungsten occur in very close association in Burma, so this chapter should be read in conjunction with the preceding one. Quartz veins containing wolfram have been located at several places in Burma over a distance of 750 miles, extending from the Southern Shan States through the districts of Kyaukse, Yamethin, the sub-State of Bawlake in the Karenni hills to the Thaton, Amherst, Tavoy and Mergui districts. In all these localities the wolfram- and cassiterite-bearing veins are intimately associated with the granite that builds the core of the ranges of the Indo-Malayan system, which extends farther south through western Siam to Malaya. In fact, in the whole belt of country, about 1,000 miles in length, extending from the Southern Shan States to Singapore, ores of tin and tungsten occur ; in the south tin is dominant, in the north tungsten. The granite in the Tavoy and Mergui districts is intrusive into the Mergui Series.

Mode of Occurrence.—Both wolfram and cassiterite occur as accessory minerals in the granite and also in the true aplite and pegmatite veins and quartz-mica-rocks associated with it. But the bulk of the output comes from the quartz veins, which are intrusive into either the granite, or its contact with the adjoining Mergui Series, or sometimes penetrate the latter alone though not far away from the granite. These veins are composed of the dense milky-white variety of quartz ; mica is nearly always present and sulphides are common. The veins have been formed by the infilling of fissures and often occur in parallel groups of overlapping lenses, which are frequently very irregular, thinning out and thickening again, splitting and then reuniting. Their length varies considerably : some in the granite have a proved length of many thousands of feet, and every gradation exists from large, well-formed veins to small, insignificant stringers.

The general strike coincides with that of the main mountain trend, *i.e.* from north–south to north-east–south-west; while dips are usually high. Composite veins are common and may be observed in any large mine, which would tend to prove that the original fissure continued to be a plane of weakness and injection after the first infilling.

The distribution of wolfram in the veins is exceedingly erratic, but this is a well-known feature of the occurrence of tungsten ores in all parts of the world. The biggest "slugs" of wolfram have weighed up to a ton, but any profit obtained from these is consumed in driving through the barren ground to find the next one.

Principal Types of Detrital Deposits.—Most of the lodes occur near the crest of the hills, and the weathered material is washed down by streamlets into the river valleys; hence there is a concentration of ore in the beds of the smaller streams in the steep-sided valleys and on the floors of the main ones. There are three principal types of alluvial or "float" deposits. (1) Within the granitic area the float consists of large boulders of granite with weathered and comminuted débris from the lodes filling the interstices between them. This type of deposit is difficult to work on account of the size of the blocks. (2) In the lower ground a similar deposit occurs, but consists of boulders of quartzite with the lode material between and under them. (3) On the softer slates and schists the deposit consists of a sticky clay which is difficult to work. Along the smaller streams in the hills the float may be only two or three feet thick; but in the main valleys it may accumulate to a much greater thickness. Along the hill-streams the wolfram is found in the float in crystals occasionally as large as a man's fist; but it does not travel far, and in the lower valleys it is found in a finely divided condition, and there is much loss in employing hydraulic methods. The composition of the concentrates obtained varies considerably: some samples contain over 70 per cent. of tungsten trioxide (WO_3), while others may contain as much as 36 per cent. of cassiterite. Hence magnetic separation is necessary. The proportion of tin, as a rule, is found to be higher at deeper levels.

Mineral Association.—The minerals found associated with wolfram are not the same in all parts of Burma. Beryl has only

been recorded from Bingyi in the Yamethin district. Tourmaline is commonly found at Mawchi in the Karenni Hills, in the Thaton district and in parts of Mergui; but in the Tavoy district it is as yet unknown in association with wolfram and cassiterite. Here, the quartz veins, in addition to tinstone and wolfram, carry mica almost invariably, fluorite frequently and molybdenite sometimes. Pyrrhotite has been recorded in some cases; galena, zinc-blende, arsenopyrite, native bismuth, and bismuthinite are rare, while topaz has been found in one case only. Bismuth, molybdenite and sulphides of copper and iron appear to increase in amount downwards. The mode of origin of the wolfram deposits described in the following pages is the same as described for tinstone in the preceding chapter.

MERGUI DISTRICT.

History of Mining.—In the Mergui district, though tin-ores have been sluiced by the Chinese and Siamese settlers for the last two centuries, yet the extraction of wolfram dates back only to 1909. A great impetus was given to the wolfram industry by the war. There was a great shortage of tungsten in England owing to the stoppage of German supplies, and, as the ore was essential for the manufacture of high speed steel alloys, the British Munitions Department and the Government of Burma gave special facilities to miners in this province and at the same time guaranteed purchase of the ore at a fixed price, which arrangement was discontinued in 1919. Consequently the market price fell from 55 to 30 shillings per unit containing 65 per cent. of WO_3. Simultaneously, the production in China increased and the miners in Burma could no longer compete with their prices. Wolfram mining, as such, has practically ceased, and wolfram is obtained only as a bye-product of tin mining from the mixed concentrates.

Important Ore-bearing Areas.—Ores of tungsten occur in the Mergui district in association with tin ores, especially in the northern portion of the district, and in the Tagu area in quartz veins traversing granites and sedimentary rocks. Below are described some of the important tungsten-bearing areas and mines.

The Palauk Area.—The mines of the Palauk area lie at the sources of the two chief tributaries of the Palauk *chaung*. At the Saku (Kethe) mines of E. Ahmed the veins are one foot wide with an east–west strike, which changes to north-east and south-west. Granite is not exposed in this mine, veins traversing the sedimentary rocks and alluvial deposits being worked. Eluvial deposits were formerly worked on the hill-slopes near the Ngaku, Shauk, Kanako, Aing, Magot, Wagunpyu, and Kathadok *chaungs*. The veins range in width from 6 to 12 inches in the Kathadok *chaungs* and have a north-north-east to south-south-west strike. A deserted mine occurs on the slopes of the Hkyekhat taung peak, at an elevation of 2,870 feet. This mine was worked during the Great War and produced mainly wolfram.

Spider Island.—Spider Island, a small hill with a height of 221 feet, is situated at the mouth of the Palauk river. It is composed of the Mergui sedimentary rocks, which are traversed by narrow, irregular quartz veins carrying both tin and wolfram. The reefs, which are rich, are only three to six inches wide and strike east 20° north to west 20° south. The mixed concentrate is obtained by sluicing the alluvium of the beach and mangrove swamp at low tide. Sethu Rama Rao believes this area has not been properly tested and valued, and is worth systematic boring. It was worked during the Great War and yielded concentrates containing equal quantities of tin and wolfram.

The Palaw Area.—Tin mines are situated at the headwaters of the Palaw river, which traverse a mineralised zone extending from Shanthe to Kadinngepya over a distance of nearly 16 miles. Many small outcrops of muscovite-tourmaline-bearing pegmatite lenticles, some of which are rich in tin-ores, occur in the area. Along the Impon *chaung* the débris from the granite exposed at the source of the Shanthe *chaung* is worked and contains cassiterite also. The alluvial deposits found at the source of the Madaw, Migyaunkthaik, Kyaukpya, Pakangyipya and Kadinngepya and the sedimentary rocks near the contact with the pegmatites were worked during the war boom.

The Tagu Mines.—The Tagu mines occur on the slopes of a hill range about 12 miles north of Tenasserim town and are

easily accessible from Mergui by water up to Sindin and Tagu. This area is one of the largest producers of tin and wolfram in the district. Between the years 1914 and 1918 the average monthly yield was 14 tons, most of this being wolfram; but there was a complete stoppage in 1920. The quartz veins of the Tagu mines vary from 3 to 15 feet in width. The strike varies from east to west to east-north-east to west-south-west. In the Kuntabin section wolfram and tin are associated with sulphides of iron, copper and arsenic. During the war lode mining was fully active, and the eluvial deposits on the hill-slopes were also exploited.

Theindaw Mines.—The Theindaw mines are situated near the source of the Theindaw *chaung*. The hill range extending from Pondawtaung to Theindaw taung, on the left bank of the Tenasserim river, consists of the Mergui Series, traversed by quartz veins which are mainly tin-bearing.

The Manoron Mines.—The Manoron mines lie near the source of the Khe *chaung*, a westerly-flowing tributary of the Manoron *chaung*. The mines are about 10 miles due east-north-east of the junction of the Lenya river and the Manoron *chaung*. The Hin-ta-khun, Kyaukthonian and Taukte *chaungs*, tributaries of the Khe *chaung*, carry ore derived from the margins of the granite and from the disintegration of quartz stringers intruding the granite and the Mergui Series. Sethu Rama Rao states that, on account of the inaccessible and unhealthy nature of the country, the area has not been fully explored, but it deserves careful prospecting as the geological conditions are favourable.

The Yengan Mines.—The Yengan mines are situated east of the village of that name on the mainland. Yengan hill is composed of the Mergui Series, traversed by quartz veins, with a north-north-west to south-south-east strike; also by pegmatite veins, one to one and a half feet in width, containing large crystals of tourmaline and muscovite. The whole area has suffered much denudation, and detrital deposits have accumulated in the shallow water close to the shore. The coastline and the creeks north and south of Yengangyi deserve careful exploration with a view to dredging. Lying in the same mineralised belt are the mines of Migyaung *chaung* and Sadein.

Bokpyin Mines.—The Bokpyin mines are situated in the valley on the eastern flank of the Yanngwa range, drained by the Bokpyin *chaung*, flowing north, the Hangapru *chaung*, flowing south, and the Yanngwa *chaung*, which follows a north-easterly direction to join the Lenya river. The country is composed mostly of the argillites and sandstones of the Mergui Series, which in the western part of the valley are intruded by many lenticular patches of pegmatite and quartz stringers of varying width. The mineralised zone contains many important tin mines, which have been worked for a long time. The width of the pegmatites, which are much decomposed, ranges from a few feet to 80 feet; while the quartz veins vary in thickness from half an inch to 10 feet. The narrower veins are richer than the wide veins. The peripheries of the main granites are transformed into greisens.

The western side of the Bokpyin *chaung*, from its very source up to the village of Bokpyin, is worked by Siamese and Chinese settlers of Inner Bokpyin. The eastern slopes of the range, on which the following streams rise, are the localities containing detrital and eluvial deposits suitable for systematic mining:

(1) Phuruk Tew and other easterly tributaries of the Upper Bokpyin.

(2) Khaothanpi *chaung*, Thapannang *chaung* and other easterly streams forming the Yanngwa *chaung*, near its source.

(3) Klong Pru Nang and the source of the Hangapru *chaung*.

Hangapru Mines.—The mines of Hangapru are situated north of the village, and eluvial deposits on the surface of a small hill are worked. Narrow stringers of quartz traversing the sedimentary rocks, which are deeply weathered, are worked in open quarries. The general appearance of the veins in the country rock is that of a "stock work."

Karathuri Mines.—The mines of Karathuri are situated in the middle of the chain of granite bosses which, extending from Bokpyin to Maliwun, form detached outcrops at the surface but are probably connected underground. The granite is intrusive into the sedimentary rocks, which are traversed by pegmatites and quartz veins. Marine denudation has sorted the débris of these, and most of the mining, which is restricted to the western side of the range, is carried out on the alluvial

flats and in the detrital areas ; lode mining is not practised. The eastern side, though covered with jungle and difficult to work, in the opinion of Sethu Rama Rao, deserves systematic prospecting.

Mining is also carried on in the islands north of Karathuri, *e.g.* Kayaukgyi *chaung* and also on those lying to the south-west, during the rains, when a sufficient supply of water is available.

Banhuni Area.—The mineralised zone of the Banhuni area forms the southern continuation of the Karathuri zone, and the mining area is situated between two ridges of quartzite and conglomerates. Alluvial and eluvial deposits have been worked here for a long time by Chinese and Siamese settlers, but there are still many promising areas in the neighbourhood which are but little explored.

Maliwun Mines.—Maliwun constitutes one of the well-known mines of the district, and is situated on the flanks of a granite range which extends from Victoria Point to Talobusa. Tin-ore in association with wolfram occurs in the quartz veins which strike from north-north-west to south-south-east, and in greisens at the periphery of the granite. Wolfram, cassiterite, sulphides of iron and arsenic occur in the lodes, which vary in width from half an inch to 15 feet. Lode mining yields cassiterite and wolfram, while alluvial workings yield the former only. Tin mining in this area was originally started by the Chinese and Siamese settlers, who exploited the deposits by the old method of sluicing with rain water. The richness of the area attracted European enterprise first in 1897, and since then it has changed hands several times.

Lampi (*Sullivan*) *Island.*—The island of Lampi, along with most others forming the Archipelago, is composed of micaceous slates and quartzites of the Mergui Series into which have been intruded quartz veins and aplite dykes, with a general north-to-south direction. They continue south into the islands of Pulo Bada and Pulo Nala. The beach deposits at Lampi were worked by Salons, sea gypsies, who bartered tin concentrates for salt, etc. Water is very scarce, and the pay gravel and soil is carried in bags to the shore and sluiced on the beach at high tide.

TAVOY DISTRICT.

History of Mining.—The output of wolfram in Tavoy exceeds that of any other district in the province. The earliest reference to the occurrence of wolfram is by Dr. Mason in 1850, who wrote : " The tungstate of iron or wolfram sand much resembles tin, and it is found in most neighbourhoods where that ore is obtained, and for which it is often mistaken. One of the Assistant Commissioners a few years ago reported several valuable deposits of tin, not before known, and he raised his furnaces on the ground to smelt the ore ; but although he tried hard, and increased the heat to the highest point he was capable of doing, still the ore remained refractory and would not turn into tin. He attributed the fault to his furnaces and came away with large specimens of tin ore, which proved on examination to be tungsten or wolfram sand." In 1909 J. J. A. Page drew attention to the occurrence of wolfram associated with tin in this district. In 1910, when mining commenced here, the world's production was about 6,000 tons of 60 per cent. WO_3 per annum, and this came from the United States of America, Portugal, Queensland, with smaller amounts from the Argentine, Bolivia and New South Wales. By the year 1911 wolfram mining was thoroughly established in the Tavoy district, and Burma, with its output of 1,300 tons, became the leading wolfram-producing country in the world. This position she maintained until 1916, when the boom caused the production of the United States of America and Bolivia to exceed hers. During 1914, out of the world's total production of 8,000 tons, Burma contributed 2,300. From the commencement of the war to the end of 1918 no less than 17,636 tons of wolfram valued at £2,322,000 were shipped to the United Kingdom.

Below are described only the important wolfram mines in the district. In 1917 mixed concentrates of wolfram and tin were produced from 132 separate concessions in this district ; but most of them are small, as over 60 per cent. of the total output of 3,653 tons came from six mines only. The largest mines during the war boom were Hermingyi, Kanbauk, Widnes, Pagaye, Paungdaw, Taungpila and Kalonta.

Mines of the Coastal Range.

Kambay.—The concentrate obtained from the Kambay mine is practically free from tin and is obtained from a vein varying in thickness from one and a half feet to three feet. Granite occurs in the big range to the west.

Kanbauk.—The Kanbauk mine is situated in a narrow valley in the sedimentary rocks of the Mergui Series covered by thick alluvial and detrital deposits. The main vein system strikes east-to-west and dips at about 60° to the south. There occurs a second series at Kanbauk West and a third at Thingagun. Granite forms the hills surrounding the valley. The mine is extensively developed underground and the ore is crushed and the concentrate recovered in a mill. The surface deposits are treated by hydraulic giants and by electrically-driven pump dredges.

Taung-Shun-Taung.—The mine of Taung-Shun-Taung is four miles west of Kanbauk and on the eastern flank of the Coastal Range. The veins are similar to those of Kambay, and the concentrates carry a high percentage of cassiterite.

Kechaung and Pachaung.—These mines are situated between Kanbauk and Egani, and both of them work on the same vein system with a general north-to-south strike. The concentrate from both consists of clean wolfram.

Mines of the Bolintaung-Byaukchaung Range.

Byaukchaung.—The ore in this mine is derived from very numerous thin stringers and greisen bands penetrating the granite and shedding the minerals into the surface soil as the rock decomposes. The concentrates contain little cassiterite, and most of the output is derived from the surface deposits.

Kalonta.—The Kalonta mine is situated on a small granite boss, in which a group of veins occurs with a north-north-east to south-south-west strike. The rock, as in the immediately preceding case, has been altered to greisen.

The Kyaukanya-Peneichaung Ridge.—The granite is exposed at both Kyaukanya and Peneichaung in this ridge. The concentrate from these mines is free from cassiterite. About midway between the two localities the great Kadando vein

crops out. It has been traced for thousands of feet, with a width of three to five feet and more. It carries wolfram with large quantities of pyrite, chalcopyrite and pyrrhotite.

Pagaye.—The Pagaye mine belongs to the Bombay-Burma Trading Corporation, Limited, and is about three miles from Pein-né-chaung and on the same strike-line. Here a large number of wolfram-bearing pegmatites and quartz veins are found in argillites. The detrital deposits on the slopes also carry these ores.

Hermingyi.—The great Hermingyi mine, probably the largest wolfram mine in the world, is situated on a granite exposure. In 1917 the mine produced 1,051 tons of concentrate out of the district's total of 3,653½ tons. The veins occur in both the granite and the sedimentary rocks which overlie it. Some of them have been followed for hundreds of feet. The detrital deposits on the slopes are of great extent, and provide much of the output in the rainy season. The concentrates carry a large proportion of tin ore.

The Central Range.

The large granite intrusion of the Central Range commences about a mile to the south-south-east of Hermingyi. It is over 30 miles in length and rises to an elevation of more than 5,000 feet above sea-level. At one place it is only half a mile in width, but it broadens out to at least 6 miles, 20 miles farther south. Practically the whole of the ground covered by this intrusion, with its surrounding contact zones, is held under mining leases or prospecting licences. The southern portion in places is covered by patches of the Mergui Series, which represent the last remains of the roof of the granite. The following important mines are situated on it.

Taungpila.—The northern section of the mines of the Central Range comprise the Taungpila group, the most important of which is Qua Cheng Guan's Taungpila. It adjoins the corner of the Hermingyi lease and like its bigger neighbour yields both tin and wolfram.

Wagon.—South of the preceding group lie the mines of the Wagon area, the most important of them being Thingandon and Wagon. Both carry a number of veins and patches of detrital

ground. East of the Central Range in this section, and about three miles from it, is a parallel ridge known as the Kyaukmedaung, built of sedimentary rocks and attaining an elevation of 2,000 feet above sea-level. On this ridge lie the mines of the Wagon North and Rubber Mile. Molybdenite in the former occurs in more than usual quantities.

Putletto and Widnes Mines.—The southern group of mines on the Central Range comprises the Paungdaw section. The most northerly one, Putletto, has a group of parallel veins carrying good wolfram values.

South of Putletto is the Widnes Mine of the High Speed Steel Alloys Mining Co. Ltd. It is situated in the granite, but there are inliers of the Mergui Series. In the western part of the mine at least seventeen veins are being systematically developed underground. They all contain wolfram with pyrites and occasionally molybdenite. A large concentrating plant was installed in 1918. The detrital deposits are treated by monitors.

Next to the Widnes Mine is the Paungdaw Mine, owned by Steel Brothers and Co. Ltd. Other mines in the area are owned by Tatas Ltd. and the Burmese Wolfram Co. Ltd. The mineral association is a sulphide one and the tin content is low, although in individual veins it is fairly high.

Three miles beyond the southern edge of the Paungdaw granite are the mines of the Meke area, owned by the Chinese, while the Pe concessions are situated in the southern Coastal Range much farther north.

AMHERST DISTRICT.

Specimens of wolfram have been obtained from the neighbourhood of Ye, near the borders of the Amherst and Tavoy districts. The mineral is also stated to occur in the Dawna range, on the Siam frontier, but no output has been recorded.

THATON DISTRICT.

The cassiterite and wolfram deposits of the Thaton district all lie on the elongated ridge which runs parallel to the railway from Pegu to Martaban.

The wolfram-bearing veins occur in two well-marked series: one in the granite and the other in quartzitic sandstones, argillites and grits. They differ markedly from those in the Tavoy and Mergui districts in containing tourmaline as an accessory mineral and in possessing a marked foliation with jointing trending in a north-west to south-east direction. The veins, which are in the nature of pegmatites, run parallel to this jointing direction. Besides tourmaline as a constant accessory, other minerals forming the veins are quartz, muscovite and probably felspar. In addition to wolfram they carry pyrite, chalcopyrite, arsenopyrite and molybdenite. Four veins occur close together with an average thickness of four inches and have been traced for the remarkable distance of two and a half miles. Beyond their southern termination two other somewhat thicker veins dip in the opposite direction and show a more irregular strike.

The veins in the sedimentary rocks occur some distance to the east of the granite, in country of much lower elevation. They dip to the west at comparatively low angles and are thicker but much less continuous than those in the granite, wolfram and quartz being the chief vein minerals.

Mawchi Mines, Karenni Hills.—The occurrence of wolfram at the Mawchi mines in the sub-State of Bawlake has been described in the previous chapter. The wolfram and cassiterite occur in flat masses near the walls of the lodes and in nests and patches throughout, and the two ore minerals occur both separately and as intimate mixtures. The veins are worked by up-to-date methods and the concentrate recovered in a modern mill.

YAMETHIN DISTRICT.

The wolfram-bearing area occurs in the vicinity of the summit of the Byingyi, 6,254 feet above sea-level on the borders of the Yamethin district and Loi Long State, Southern Shan States. The veins are all in the granite, and possess a general north-west to south-east strike and dip south-west, sometimes at low angles. Beryl is a common but unique associate of this wolfram occurrence. Molybdenite occurs invariably, but cassiterite is wanting.

SOUTHERN SHAN STATES.

In the Myelant division of the Southern Shan States, granites, clay-slates and quartzites are penetrated by veins carrying wolfram, molybdenite and copper and iron compounds.

Yawghwe.—On the western flanks of hill 4,832 to the east of Pawhamaw (20° 37′, 96° 52′) and near the southern end of the Heho-Mawnang plains, there are numerous dumps from old trenches and pits which were formerly worked for wolfram. According to J. Coggin Brown the country rocks are mainly hard, fine-grained siltstones crossed by thin quartz stringers and veinlets. The latter contain muscovite, either lining the veins or segregated into patches, or more often forming a thin wall between the quartz vein and the host rock. Wolfram occurs in thin plates and crystals irregularly distributed through the quartz. It is usually profoundly decomposed or even completely removed, leaving empty spaces, sometimes filled with cindery oxides of iron and manganese and rarely showing a film of tungstite. Judging from the distribution of the old workings the stockwork occurs in a broad zone running approximately north-and-south and a few hundred feet wide.

METHODS OF MINING.

In the early days from 1909 onwards most of the ore was obtained by Chinese, working with pans and rough sluices, rich patches on the hill-slopes and in creeks. These methods entailed considerable wastage. Later, work was based mostly on the tribute system, but during the war boom a greater proportion of the wolfram concentrate was obtained by sluicing shallow detrital deposits, or by hand-crushing quartz from the outcrops of veins. The rocks in this very humid jungle-covered area are completely rotten, sometimes down to considerable depths, which greatly facilitates sluicing operations. In the mines situated in the harder rocks the methods of lode-mining are employed, and the requisite machinery has been installed at some of the larger mines, *e.g.* at Hermingyi and Kanbauk. Below is given a brief description of the mining plant employed at the latter mine.

Mining and Milling.—The lodes are developed by a series of drives from 60 to 100 feet apart vertically, and the ore is trammed to gravity inclines and thence to the mill, which consists of ten heads of stamps, four Wipley tables, magnetic separator, etc.

Hydraulic Sluicing.—Water is brought to the mine by two steel flumes, of capacity 25 to 35 cubic feet per second respectively and of a total length of about three miles. The working pressure varies from 125 to 150 lb. per square inch, while the equipment includes four 8-inch and two 12-inch monitors with nozzles ranging from two to four inches.

Two hydraulic elevators are used to raise the gravel to heights of 50 and 45 feet respectively, but the former has been replaced by a 12-inch gravel pump mounted on a pontoon and driven by a Pelton wheel. This pump will lift to a total height of 8 feet and enable deeper ground to be worked.

The water and gravel are passed over " grizzlies " with one-inch spaces, the stones being passed down a steel chute to the end of the boxes, where they join the main flow in the tail race. Two main sets of boxes are used, and each contains three compartments 12 feet in width and 130 feet in length. They are cleaned up about once a month by sluicing with a fire hose and elevating the concentrate to the cleaning box with a six-inch hydraulic elevator. As the concentrate contains large amounts of magnetite, it has to be passed through the magnetic separator. A hydro-electric plant to operate a pump-dredging plant, the mill, the workshops, and the electric drills and separator has also been installed.

USES OF TUNGSTEN ORES.

Tungsten is largely used as an ingredient in the manufacture of " high-speed-tool-steel," instruments made of which are capable of resisting friction much more so than carbon steels, which lose their cutting properties when the temperature rises beyond 500° F. The addition of tungsten raises the melting point and imparts self-hardening properties to the steel. Again, steel hardening in the smithy is rendered considerably easier when cutting instruments are manufactured from tungsten steel. It is also used for the preparation of permanent magnets,

for the valves of special makes of internal combustion oil engines, as contacts for sparking plugs, for tremblers and voltage regulators, as a constituent of "stellite" and other alloys, such as the alloy with aluminium known as "partinium," as an alloy in dental and surgical instruments, in gramophone needles and as a catalyser for the production of ammonia from atmospheric nitrogen and hydrogen. The high melting-point of tungsten, combined with the toughness and fineness of the wire into which it may be drawn and its behaviour under the action of an electric current, make it the best material known for incandescent electric lamp filaments, and very large numbers of these tungsten bulbs are now in daily use. But the quantity of tungsten required for this purpose is unfortunately very small.

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CHAPTER XII

SALT.

No true rock-salt deposits occur in Burma, but salt has been obtained by boiling the brine from springs, wells, saline soil, etc., in the dry zone and other parts of Burma. Besides, in the coastal districts, salt is obtained by boiling the sea-water.

Northern Shan States.—The manufacture of salt from the brine well at Bawgyo (22° 35′, 97° 16′), a large village on the bank of the Nam-Tu and six miles east-south-east of Hsipaw, has been described by Noetling and La Touche, who visited the locality in June 1890 and December 1905 respectively. According to the latter the well is square in section, measuring four feet by three feet eight inches, and is about 45 feet deep. The brine at the time of La Touche's visit stood at about seven feet below the surface of the ground, and it is apparently very much weakened during the rains,[1] as is shown by the following results :

	Sample collected 8th June, 1890.	Sample collected 19th December, 1905.
Water - - -	87·47 per cent.	74·42 per cent.
Total Salts - -	12·53 ,,	25·58 ,,

The brine is boiled in two shallow iron pans, each holding about six gallons, and it takes two hours for the necessary evaporation to be completed ; the yield of each pan at the time of La Touche's visit weighed 4½ *viss*, or 16·42 lb. The level of brine in the well rises at the rate of three inches an hour after the boiling has ceased. It would, therefore, take 44 hours to fill up the nine feet, or about 1,000 gallons, required for a day's

[1] In Burma there is a very well-marked rainy season from June-September.

boiling. The average analysis of the solid contents of two samples of brine are given below :

Sodium Chloride - - - - - -	60·39 per cent.
Sodium Sulphate - - - - - -	35·44 ,,
Calcium Sulphate - - - - - -	0·60 ,,
Magnesium Sulphate - - - - -	0·75 ,,
Undetermined (Potassium, etc.) - -	2·86 ,,
	100·04 ,,

La Touche estimated that the total quantity of sodium sulphate available, if required for the wood-pulp industry of Burma, would be 70 tons per annum.

Myitkyina District.—Several salt springs occur in the Myitkyina district, but the more important are those of Mabawmaw or Lama (25° 42′, 96° 21′) in the Kamaing sub-division, which supply almost all the salt consumed locally in the Kachin Hill tract. Two important springs lie close to the bed of the Mabaw *hka*, and the third one exists in a tributary stream about three furlongs north-west of Lama. The main salt spring occurs on the right bank of the stream and is about ¼ mile north-west of the village. It is a shallow well nearly eleven feet deep and over nine feet in diameter. A gallon of brine collected here in December 1928 was found to contain 2867·82 grains of solid residue, which on analysis yielded the following results :

Sodium Chloride - - - - - -	78·29 per cent.
Potassium Chloride - - - - -	14·21 ,,
Calcium Chloride - - - - - -	6·38 ,,
Magnesium Chloride - - - - -	0·70 ,,
Calcium Sulphate - - - - - -	0·62 ,,
Insoluble Matter: Inorganic - - - - -	0·08 ,,
Insoluble Matter: Organic - - - - - -	traces
	100·28 ,,

All the activity at the time of the writer's visit in December 1928[1] was centred round the first spring. Four furnaces, oblong in shape, were being worked at the time. Brine is heated in iron cauldrons over a furnace. Boiling is carried on day and night, and the yield of one furnace in twelve hours was stated to be five to six *viss*, or about 20 lb. These springs are considered

[1] *Rec. Geol. Surv. Ind.* vol. lxiii, 1930, pp. 49-50.

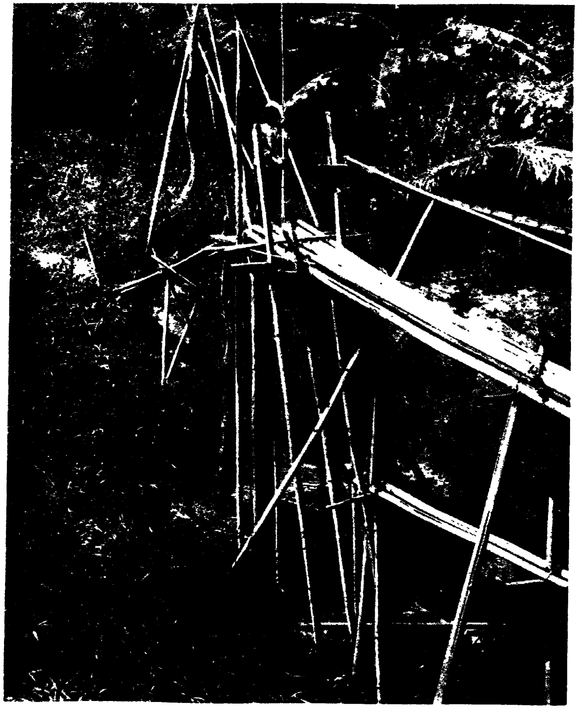


FIG. 1.—THE BRINE-SPRING OF IDIMAW IN THE HUKAWNG VALLEY.

Arrangement for lifting and carrying the brine in split bamboo

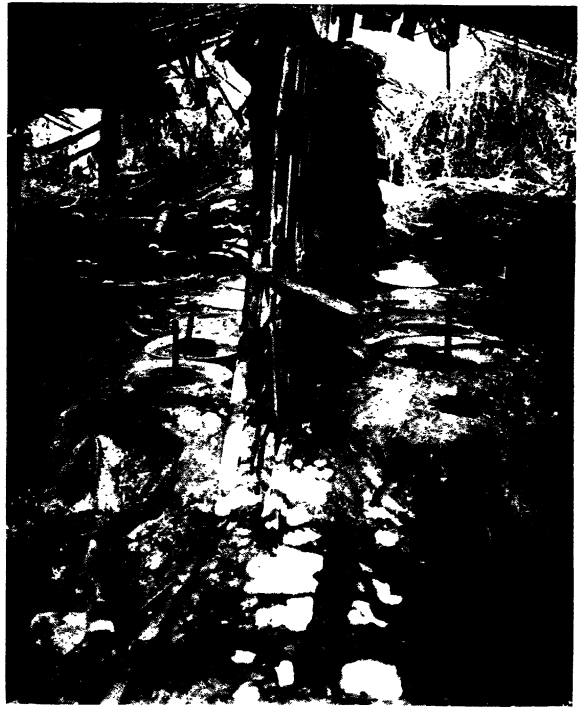


FIG. 2.—SALT FURNACES AT MALUNG JUM (26° 3′, 97° 1′) HUKAWNG VALLEY.

to lie along a fault, forming the western boundary of the Mabaw siliceous agglomerate. The second locality where salt is boiled is known as Kyum *hka* (25° 41′, 96° 23′). The spring is situated in the Tertiaries in the bed of a small stream. It has been converted into a small well, about five feet deep. Sulphuretted hydrogen escapes, but not so briskly as in the case of Mabawmaw.

Several other brine springs are also known in the Myitkyina district, and salt is frequently manufactured by the local Kachins at these localities.[1] Important salt springs also occur farther south in the neighbourhood of Mawhoon.

Hukawng Valley.—Several salt springs occur in the Hukawng valley, and the writer[2] visited those of Idimaw (26° 55′, 96° 33′), Dige Jum (26° 16′, 96° 30′), Namsapmaw (26° 14′, 96° 33′), Yamutmaw (26° 11′, 96° 31′), Jumting Jum, Kahpan Jum (26° 9′, 96° 57′), Pung Jum (26° 7′, 97° 4′), Malung Jum (26° 27′, 97° 3′), Jumnan Jum (26° 27′, 97° 2′), Maren Jum (26° 25′, 97° 3′), Bra Jum (26° 20′, 97° 3′) and Jumbrauk Jum (26° 19′, 97° 3′). The last five of these are apparently situated on a fault-line, which runs roughly in a north-south direction for about nine miles in the Lower Tertiaries. Two additional springs, Matau Jum (26° 4′, 97° 1′) and Malung Jum are not improbably situated on a southerly extension of the same fault. Whilst the majority of the springs are associated with Tertiary rocks, the salt spring of Kahpan Jum lies in crystalline schists.

Several of these springs have been converted into wells by lining with bamboo matting or a hollow tree-trunk (see Plate IX, Fig. 1). The brine is boiled in furnaces, sometimes of seven or eight iron cauldrons, or in bamboo troughs, 75 of which were placed in one furnace (Plate IX, Fig. 2) at Malung Jum, the richest brine locality at present known, and a gallon of brine collected in April 1930 yielded 7,040·64 grains of the solid residue consumed locally as salt. Samples from other springs yielded from 1,438·15 grains (Malung Jum, 26° 3′, 97° 1′) to 4,896·74 grains (Idimaw) of solid contents per gallon. As an example of yield, one furnace with eight iron cauldrons at Idimaw gave an average yield of 7½ *viss* (one *viss* = approxi-

[1] *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, pp. 71-72.

[2] *Ibid.* vol. lxv, 1932, p. 63.

mately 3½ lb.) after twelve hours' boiling; during the rains the output is said to decline to four or five *viss*. The fuel used for boiling is, of course, wood, which occurs in abundance in the neighbouring jungles.

Katha District.—In the Katha district Noetling mentions the occurrence of a series of salt springs situated on the western side of the Maingthon hill tract in Wuntho. The springs occur in beds of volcanic ash in a N.N.W.–S.S.E. belt, probably marking the line of a fault, and usually rise in the beds of streams.

Dry Zone, Upper Burma.

Salt is of common occurrence in the Tertiary rocks, especially in the dry zone of Burma, and in the past large quantities of salt were won in the districts of Shwebo, Sagaing, Upper Chindwin, Lower Chindwin, Magwe, Pakokku, Myingyan and Yamethin. Even at the present day salt is made in numerous places, either from brine wells, but largely from lixiviating the saline soil. Salt is recovered by boiling the solution.

Shwebo and Sagaing Districts.—The manufacture of salt is carried on at a number of villages in the Shwebo district, of which the group of villages collectively known as Halin constitutes by far the most important centre.[1] Here, as in most other localities in the dry zone, the salt is derived from the Irrawaddian beds, near the western boundary of which all the localities lie. Salt is leached out from the Irrawaddian sandrock and carried in solution over the surface or underground to the low-lying ground, resulting in its gradual accumulation there. During the dry season these salt solutions are drawn to the surface soil by capillary action. The soil, when sufficiently rich, is scraped up and piled into small mounds. The brine is poured into a bamboo-pipe inserted in the basin-shaped hollow made in the pile and a rich salt solution then trickles down it. The filtered solution, containing about 18 per cent. of salt, is evaporated in rectangular iron pans of seven gallons capacity. It is reported locally that from 35 *viss* (one *viss* = approximately 3½lb.) of soil, six *viss* of brine and 1½ *viss* of salt can be obtained.

When, however, the brine is not sufficiently near the surface

[1] *Rec. Geol. Surv. Ind.* vol. lxv, 1930, pp. 63-64.

to be drawn up by capillary action, wells are dug in the ground and the brine hauled up and spread over a harrowed field, as described below in detail. According to Mr. E. G. Robertson [1] the salt manufactured in the Shwebo district is very impure and has the following chemical composition :

Sodium Chloride	76·57	per cent.
Magnesium Chloride	0·46	„
Calcium Chloride	3·26	„
Calcium Sulphate	1·71	„
Ferric Oxide and Alumina	0·17	„
Insoluble Inorganic Matter	0·19	„
Water	17·64	„
	100·00	„

According to Mr. E. J. Bradshaw the salt-fields of (1) Sadaung (22° 9′, 95° 45′), (2) Minbo (27° 7′, 95° 52′), (3) Baukthauk (22° 8′, 95° 50′), (4) Kongyi (22° 8′, 95° 50′), (5) Tagalet (22° 14′, 95° 49′) occur farther south in the Shwebo and Sagaing districts.

The method of making salt is about the same in all the fields, except for some minor modifications. Wells, about three feet in diameter, are dug to a depth of from 30 to 35 feet and riveted or lagged with wicker-work or bamboo matting. The brine is hauled up in earthen pots and left for some time to concentrate in the sun and is then scattered over sandy soil, raked by hand or with the aid of buffaloes. When the water has evaporated the sand is harrowed either with large wooden rakes or by harrows drawn by buffaloes.

The salty sand is then dumped into filters, which are cylindrical hollow heaps of sandy clay from four to five feet in height and with a hollow bamboo serving as an outlet near the base. Brine from the pond is poured over the salty sand in the filter, and percolating through is both enriched and filtered. In some cases efflorescent sand, "*sapaya*," naturally rich in salt, is transported from a distance and mixed with the saline sand in the filters.

Finally, the concentrated brine from the filters is placed in shallow, rectangular tin pans, about one foot by two feet six inches, and evaporated to dryness over a fire in a clay oven. The salt is clean and white in appearance and, according to Mr.

[1] "Report on Preliminary Survey of the Salt Industry in the Shwebo and Sagaing districts," Government Printing, Rangoon, 1923.

Bradshaw, seems to be good in quality. At Tagalet the total daily output averages about 150 *viss* (525 lb.) of salt. The capacity is about 250 *viss*, but there is not sufficient quantity of wood available.

Mr. Bradshaw [1] considers that the source of the brine lies in the concretionary zone at the base of a fine-grained, friable, greenish, micaceous Pegu sandstone, the salt having collected there as a consequence of percolation of waters from above. He adds that the water from the springs or wells at this horizon is always salt, while that from higher horizons is sweet.

Farther south in the Sagaing district salt is also found in the Tertiary rocks which form the hills between Saye and Ondaw, as also brine from wells and springs, and as an efflorescence in the sandy deposits which form the low ground.

Oldham has described the process of making salt at Yega (21° 59′, 95° 59′), a small brackish water lake. The mud from the bed of the lake was lixiviated in straw filters, and the brine, concentrated by evaporation in iron pans, was placed in baskets, in which the salt crystallised out.

Pakokku and Lower Chindwin Districts.—Salt is manufactured extensively from clays of the Pegu series at Kyaukka in the Pakokku district and Salingyi in the Lower Chindwin district. At the former locality clay containing the salt is placed in small earthen pots in the bottom of which a small hole has been made. Water is then poured into the pot and allowed to percolate through the clay. The brine thus collected is boiled to obtain salt. At Salingyi the saline water is obtained from wells in the Pegu clays and enriched by percolation through a soaking bed prepared from loosely piled salt-bearing clay.

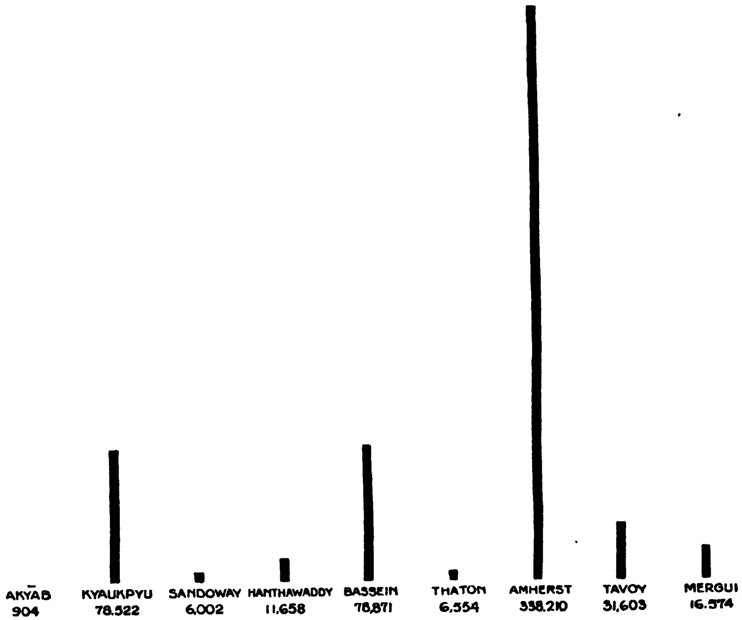
Myingyan District.—According to La Touche, salt was being manufactured in 1909 at Sagyin (20° 57′, 95° 28′) and other villages in the neighbourhood on a small scale from the saline efflorescence derived from brine springs. The soil, as described above, is saturated with water from the springs by repeated moistening and drying. The brine is then washed out in large conical wicker baskets and evaporated over a slow fire.

Thayetmyo, Prome and Henzada Districts.—Theobald [2] has

[1] *Rec. Geol. Surv. Ind.* vol. lxii, 1930, p. 64.

[2] *Ibid.* vol. vi, 1873, pp. 67-73.

given an account of the salt springs of the Thayetmyo, Prome and Henzada districts forming part of the then province of Pegu. He has enumerated 79 springs and wells which occur along three lines, roughly parallel to each other and to the eastern flanks of the Arakan Yoma. The most important spring is that of Sahdwingyi (Sanywagyi, 18° 2′, 95° 9′) which has a discharge of 57 gallons per hour, and a gallon of the brine contains 4,704 grains of salt.



Showinq the Output of Salt in Maunds for the Coastal Districts of Burma.

UNIT. ■ 5,000 = 1 UNIT.

Fig. 11.

Salt Industry, Coastal Districts.

A very large percentage of the salt produced locally in Burma is obtained by evaporation of the sea-water in the districts of Akyab, Kyaukpyu, Sandoway, Bassein, Myaungmya, Hanthawaddy, Thaton, Amherst, Tavoy and Mergui districts. The output of the important salt-producing districts is compared in Fig. 11.

The writer had an opportunity of studying the salt industry at Amherst during October 1927, which is carried on on a very extensive scale ; in fact, the output in the Amherst district is the largest in Burma. The description of the process of manufacture given below also applies in general to the places noted above. The Government are taking steps to place the manufacture on a more economical basis by introducing modern scientific methods, and it is a matter of great satisfaction that improvements in certain directions have already taken place: first, in the size of their cauldrons, and, secondly, in the design of their furnaces. Not very long ago they boiled salt in small earthen pots having the capacity of not more than a few gallons, while the capacity of the iron pans used at present varies from 70 to 150 gallons. Their furnaces have also undergone considerable modification, and they can now get over 50 per cent. additional salt with the same amount of fuel they used before.

Manufacture of salt in Burma is of ancient origin, and, so far as the British records go, salt was manufactured at Amherst when the provinces of Tenasserim and Martaban came under British rule. But it would be almost impossible to trace the earliest date, for, as is recorded by Dr. Ratton, " a history of salt is to some extent a history of civilisation. We can trace salt back in the past as far as the pages of history extend." A report by Mr. G. Plowden submitted to the Government of India in 1856 contained the information regarding the salt manufacture in the then provinces of Tenasserim and Martaban.

Concentration of Brine.—Reservoirs are filled with sea-water run through a channel or creek connected with the sea, and the flow of water in the channel depends upon the level of the locality in relation to that of the sea. If the place is on a lower level than the sea then the water replenishes the reservoir at every high tide, but at Amherst, situated at a higher level than that reached by normal tides, sea-water only flows through the channel during spring tides. In any case a sluice gate is erected at the entrance to reservoirs and is opened at high tides and closed again before the ebb commences. The sea-water stored in the reservoir mentioned above is pumped by an ingenious contrivance called a " Persian wheel " up to the beds or " solar pans " where it is concentrated by solar evaporation.

The beds or "solar pans," are merely level fields separated by low ridges of mud, and the size of these beds is variable, depending upon the topography and amount of land available. However, those at Amherst were fairly extensive, some of them measuring about 850 by 200 feet. The soil of these beds must not be porous. In the first bed the depth of water is about four inches, and the evaporation goes on for three days,[1] when it is passed on to the second bed, till the process has been repeated four times, when the depth of the concentrated brine remains only one inch, and by this time it has almost reached the point of saturation, which is 20° Beaume.

A table of suitable relative areas for each series of beds suggested by the Salt Department is as follows :

Beds.	Degrees Beaume.	Area, Square Metres.	Depth of Brine.		Contents, Cubic Metres.
			Metres.	Inches.	
1st Condenser -	3·5°	5·960	·168	6·6	1·000
2nd ,, -	7°	4·708	·113	4·4	·533
3rd ,, -	12°	4·514	·070	2·7	·316
4th ,, -	20°	2·774	·054	2·1	·144

The depths remain constant, but the areas vary in accordance with the magnitude of the works. The concentrated brine is boiled generally at a density of 22–23° B.

The writer was informed by Mr. Robertson that the concentration of brine to 22° is rather to be preferred, as at the higher density of 25° B. certain organic matter (algae) is held in suspension and tends to discolour salt during the boiling process. The concentrated brine is led finally into a storage tank. The final stage of evaporation is conducted inside a shed in which there is a small well hollowed out of the stem of a large tree, into which the brine flows automatically to a depth of about 4½ feet, by means of a bamboo pipe connected with the storage tank.

[1] These periods are, however, approximate only, as the time it takes a charge to pass through the beds varies in accordance with the amount of solar heat and humidity of the atmosphere.

Description of the Furnaces.—The furnace in vogue is depicted in Fig. 12. There is a platform, made up of bricks, about three feet nine inches high, and about eighteen feet long and about twelve feet wide, and contains three furnaces. About half-way up in front are three crescent-shaped holes about two feet wide and eighteen inches high, and these represent the mouths of the furnaces and are lined with iron sheets. The firewood is burnt inside to heat the iron pans placed above. The arrangement of these pans is also shown in the same figure.

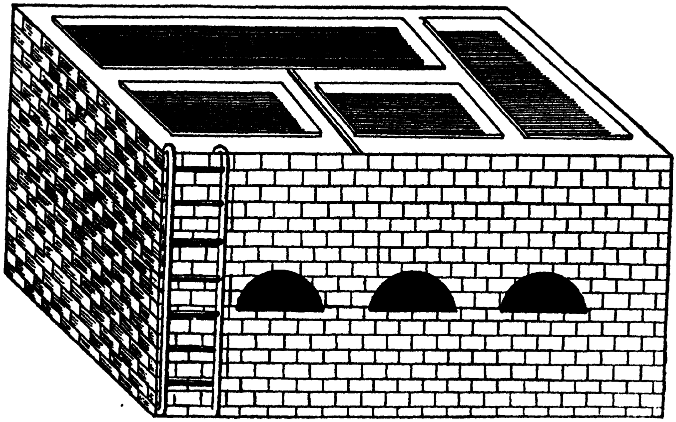


Fig. 12.—A Salt Furnace at the Government Salt Factories, Amherst.

There are two pans in front which measure seven feet six inches by five feet three inches, and are about four to five inches in depth. There is a third pan, the length of which is double the combined width of the first two pans. The third pan at the back receives less heat than the front pans, consequently it takes about twice the time for the complete evaporation of brine in the former. On the right is the third furnace, which has only one long pan of about the size of the third pan.

Brine is transferred from the well into the pans by means of a bucket which works by a kind of lever arrangement. In the pans all the brine is evaporated away in approximately three hours. A spoonful of cocoanut oil, or a little kerosene oil, or a little rice water is added to prevent the coarse crystallisation of salt and to refine it. The addition of oil retards evaporation

and increases the temperature of the brine and hence produces finer grain. The salt boilers work day and night and get about 200 *viss* of salt daily from each pan. Three men work at a furnace, by shifts of one at a time, and the men in turn add fuel and scrape the salt when evaporation is complete.

The question of fuel supply is an important problem, and it must ultimately effect the industry considerably. Steps are being taken by the Salt Department, in conjunction with the Forest Department, to provide suitable plots of forest land which will be divided into compartments to be worked in rotation.

Bye-Products.—Below are given the results of analyses of salt from Amherst district as given in Wingate and Thurley's report:

		I.	II.	III.	IV.
Sodium Chloride		88·52	72·67	91·91	92·64
Magnesium Chloride		1·86	3·99	0·16	0·47
Calcium Chloride		—	—	0·42	—
Magnesium Sulphate		0·45	1·17	—	0·35
Calcium Sulphate		2·07	2·14	1·71	0·98
Moisture		6·15	18·72	5·50	4·88
Insoluble Matter:	Inorganic	6·092	0·017	0·056	0·117
	Organic	0·041	0·0002	0·058	0·056

I. Amherst (Amherst district).
II. Panga (Amherst district).
III. Panga (Second sample, Amherst district).
IV. Karokpi (Amherst district).

A glance at the figures will show that apart from sodium chloride other salts, viz. magnesium chloride, magnesium sulphate and calcium salts are present. Mr. Robertson[1] has suggested a fairly simple and effective method of obtaining these compounds as bye-products. With regard to the recovery of magnesium sulphate alone, the following was stated by the Deputy Commissioner, Amherst, in 1916: "Incidentally I would remark that sufficient Epsom Salts (magnesium sulphate) to supply the whole of the requirements of the province can be produced as a waste-product in the salt-fields of Amherst district." The large percentage of magnesium chloride accounts for such a high percentage of moisture, as the former is one of

[1] "Note on Bye-Products from the Manufacture of Salt in Amherst district," Government Printing, Rangoon, 1920.

the most deliquescent substances known. It not only imparts an unpleasant taste to the salt, but is responsible for the considerable wastage on account of the draining of salt. During the year 1926–1927 there was a wastage of 28,572 maunds of salt in Amherst district alone. It has been suggested to eliminate magnesium chloride, which is the last product of evaporation, by washing the salt with a saturated solution of brine.

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CHAPTER XIII

OTHER MINERALS.

ALUM SHALE.

THE occurrence of alum shale near the Ynzalin river in the Salween district was reported by Brandis in the year 1862. Nothing further is known about this deposit. Mason has recorded the occurrence of this type of shale in the valley of the Myittha river in the Tavoy district. It is highly improbable that alum could be manufactured in Burma, as it has not been possible to produce sulphuric acid on a large scale (though the author has described deposits of pyrites in the Bassein district, *vide* chapter on Iron-ore Deposits), and as cheap alum is manufactured in the west from barytes.

REFERENCES.

1. Mason, Rev. F., " The Natural Productions of Burmah, or notes on the Fauna, Flora, and Minerals of the Tenasserim Provinces, and the Burman Empire," 1850, p. 31.
2. Ball, Valentine, *A Manual of the Geology of India*, part iii, Economic Geology, Calcutta, p. 435.

ANTIMONY.

The most important deposits of antimony ore occur in the Southern Shan States and the Amherst district of Lower Burma. None of these deposits, however, has been worked to any extent yet.

Northern Shan States.—Dr. Fermor has described specimens of stibnite, largely converted into cervantite, alleged to have come from a locality (22° 28′, 96° 34′) in the State of Hsum Hsai.

Fragments of stibnite, apparently derived from veins in granite, have also been found in the neighbourhood of Nam Hsan (22° 58′, 97° 12′), the capital of the Tawng Peng State, but the occurrence of the mineral *in situ* is not known.

Southern Shan States.—In this area there are about six localities where antimony ore deposits exist, the most important of them all being situated in Mong Hsu State just south of the village of Nee-hok or Nakung, on the western bank of the Nampang. Here extensive prospecting operations were carried on nearly 25 years ago, and it is recorded that during 1908 about 1,000 tons of the ore were removed, though during subsequent years practically nothing appears to have been done.

The ore, which is stibnite, is locally oxidised and converted into the oxides of antimony, valentinite and cervantite: the ore body lies in a limestone which is analogous in composition to the Plateau Limestone. As there is a thick covering of a clay deposit over the ore-body no regular work has hitherto been done, and hence it is difficult to convey any adequate idea of the amount of ore available. Analysis of the ore has indicated the existence of antimony to the extent of 70·35 per cent. in certain localities only, while in others it falls to as little as 35·42 per cent. The antimony ores in other parts of the Southern Shan States are of poor quality, so that it is hardly necessary even to mention the areas where they occur.

Amherst District.—Antimony-ore deposits are found in the extreme south-east of the Amherst district, about 9 miles from Thabyu village.

The country-rock in which the ore-body lies is a slate devoid of any stratification, and strongly resembling the argillites of the Mergui Series in the Tavoy district. A number of lodes exist, about seven in number, the biggest of which is some 600 feet long and has an observed thickness of about 20 feet. The ore is stibnite, the trisulphide of antimony, and occurs in "bunches of radiating or parallel crystals up to 4 and 5 inches long and in massive aggregates." The ore masses are generally of an irregular shape, though in many cases there is a tendency to lenticular form. They are associated with yellow and white calcareous chert, showing distinct brecciation and often a cellular structure. The ore has been found to contain, on analysis,

about 60·45–61·59 per cent. of antimony, with traces of arsenic.

Tavoy District.—Antimony ore is also stated to occur in the Tavoy district, probably in continuation of the Amherst occurrences, but no details of the deposits are known.

REFERENCES.

3. Burney, H., " Note on Mineralogical Specimens from Upper Burma," *Journ. Asiatic Soc. Beng.* vol. iii, 1834, p. 194.
4. Foley, W., " Notes on the Geology, etc., of the country in the neighbourhood of Maulam Yeng," *Journ. Asiatic Soc. Beng.* vol. v, 1836, p. 272.
5. Helfer, J. W., *Report on Amherst in the Tenasserim Provinces*, Calcutta, 1837, p. 12.
6. O'Riley, E., " Remarks on the Metalliferous Deposits and Mineral Productions of the Tenasserim Provinces," *Journ. Ind. Arch.*, iii, 1849, p. 733.
7. Criper, W. R., " Note on some Antimony Deposits in the Moulmein District," *Rec. Geol. Surv. Ind.* vol. xviii, pp. 151-153.
8. Fermor, L. L., " Ores of Antimony, Copper, and Lead from the Northern Shan States," *Rec. Geol. Surv. Ind.* vol. xxxiii, 1906, p. 234.
9. La Touche, T. H. D., " Geology of the Northern Shan States," *Mem. Geol. Surv. Ind.* vol. xxxix, 1913, p. 366.
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ASBESTOS.

It is just possible that some asbestos occurs near the serpentine masses which extend practically along the whole length of the Arakan Yoma. Until now no notice of the occurrences appears to have been taken; but their existence may be inferred from the fact that some specimens sent out by Burney from the Sagaing district are reported to be a fine silky white amianthus.

BARYTES.

This mineral is found in large quantities in association with lead-silver ores at the Bawdwin mines (23° 7′, 97° 20′ 30″). The mineral was not observed *in situ*, but fragments up to a foot in

diameter were found plentifully scattered over a wide area, apparently derived from a large vein.

The mineral also occurs commonly in the neighbourhood of Mawson (20° 57′, 96° 50′), where it is frequently associated with quartz and calcite. It is in places found in well-developed veins. V. P. Sondhi discovered an outcrop of barytes, east of Konlean (20° 48′, 96° 39′), about 5 miles west-north-west of Taunggyi. The other locality from which this mineral has been reported is in the Amherst district, where it is associated, in very small proportion, with the antimony ores of Thabyu.

REFERENCE.

12. La Touche, T. H. D., and Brown, J. Coggin, "The Silver-Lead Mines of Bawdwin, Northern Shan States," *Rec. Geol. Surv. Ind.* vol. xxxvii, 1909, pp. 242 and 255.

BISMUTH.

Nowhere in India do large quantities of this element occur. O'Riley states that sulphide of bismuth occurs associated with ores of antimony in the sandstone ranges between the Asaran and Moulmein rivers. Farther south native bismuth occurs in association with the wolfram deposits. In the Kanbauk mine it is found *in situ* in the wolfram lode. At Byaukchaung, Kanbauk and Kalonta in the Tavoy district, and at Palan in the Mergui district, it is found in the eluvial tin-wolfram deposits. The sulphide bismuthinite has also been found.

REFERENCE.

13. O'Riley, E., "Remarks on the Metalliferous Deposits and Mineral Productions of the Tenasserim Provinces, *Journ. Ind. Archipelago*, vol. iii, 1849, p. 737.

CHROMITE.

Chromite occurs associated with some of the serpentinised peridotites of Burma.

Henzada and Bassein Districts.—The author found three localities in the Henzada and Bassein districts (in addition to several minor occurrences at Myinwataung, etc.), where the

economic possibilities of chromite are worth consideration. The first is about 1¾ miles south-west of Legonywa south, near Kwingyi, on the road from the Mezali *chaung*. Here big boulders of chromite, more than a foot in diameter, were found. Some of the boulders weighed roughly about 150 lbs. and in about half an hour the author collected some 500 viss (approximately 1,800 lbs.) of ore. All this ore was found on the surface as a result of weathering, and the author is of the opinion that the mineral occurs as segregations in the serpentine, which on weathering yield large and small pieces of pure chromite, with a little serpentine. Chromite occurs associated with serpentine, etc., in a similar manner in Southern India and Baluchistan, as well as in many other parts of the world. The other Burmese localities, where chromite occurs in some quantity, are Zeitaung, 473 Hill, west-south-west of Zibinkwin village and about 1½ miles north of Shwelaungyin.

No true estimates of the quantity of chromite can be given without detailed prospecting operations. The lack of easy communication and transport facilities at present are perhaps some of the difficulties in the way of exploitation of the ore, although it is sufficiently pure and contains about 57 per cent. of chromium oxide as compared with the theoretical quantity, 68 per cent.

Farther north chromite is associated with the serpentines of the Thayetmyo district, occurring north-west of Kadaing (19° 25′, 94° 37′). It is also stated to occur in the serpentines in the Mon *chaung*, west of Longyi, Pakokku Hill tracts (20° 46′, 94° 7′).

Myitkyina District.—Chromite is associated with the peridotites and serpentines of the Jade Mines region in the Myitkyina district. The author found a number of boulders of this mineral, some of which measured over 3 feet in diameter, about 2½ miles north-east of Tawmaw (25° 41′ 13″, 96° 15′ 28″) on the road to Sanhka *hka*. Another small occurrence exists about 1¾ miles to the north-east of Tawmaw, on the same track. Both are believed to be segregations in the local ultrabasic rocks.

Water-worn boulders of chromite are sometimes found in the jadeite workings in the Boulder Conglomerate in the Uru

river. Blocks and boulders of chromite were also found by the author at the following localities :

(1) in a tributary of the Pang *hka*, nearly one mile west-north-west of Mahok (25° 44′ 8″, 96° 22′ 53″) ;
(2) near the old jadeite workings of Pangmaw (25° 44′ 53″, 96° 20′ 54″) ;
(3) on the track from Namshamaw (25° 45′ 31″, 96° 22′ 28″) to Mawsitsit, and also in the neighbourhood of Wayutmaw (25° 45′ 42″, 96° 21′ 38″) ;
(4) in the Nanjo *hka*, about 6½ furlongs north of Sanhka (25° 41′ 8″, 96° 20′ 57″), where chromite boulders are associated with a volcanic breccia ; and
(5) in the Tertiary conglomerates of Pangmamaw, east of Kansi (25° 47′ 1″, 96° 22′ 48″).

REFERENCE.

14. Chhibber, H. L., " The Serpentines and the Associated Minerals of the Henzada and Bassein Districts, Burma," *Journ. Burma Res. Soc.* vol. xvi, 1927, pp. 193-194.

COBALT.

Theobald found a specimen of earthy cobalt associated with manganese ore near Heinze (14° 29′, 98° 12′) in the Tavoy district. Erythrite or cobalt bloom occurs as a rare constituent of the lead-silver ores at Bawdwin, Northern Shan States.

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COLUMBITE.

Bleeck, in describing the wolframite lodes of the Tavoy district, observes that columbite in black orthorhombic crystals was found in all the lodes. It is definitely known that it is not associated with the tin-wolfram deposits.

REFERENCE.

17. *Mem. Geol. Surv. Ind.* vol. xliv, 1923, p. 209.

COPPER.

Copper occurs in several localities in Burma, but deposits of any economic value are hitherto unknown.

Northern Shan States.—Chalcopyrite is found disseminated in minute grains through the country rock, occurring in association with galena at Bawdwin (23° 7′, 97° 20′ 30″) in the Northern Shan States. According to La Touche and Coggin Brown, thin films of malachite and azurite, resulting from the decomposition of copper pyrites, also occur as incrustations along shear planes in the rocks.

The Burma Corporation Limited have obtained an appreciable output of copper-ore from the Bawdwin mines since the year 1912. The total amount raised during the four years 1912–15 was 2,573 tons. Since 1919, however, no returns of output of the copper ore have been available, though in that year the reserves of the ore were stated to be 300,000 tons. The ore contains silver in addition to copper, and yields 23·02 per cent. of the former and 10·9 per cent. of the latter to the ton.

Copper slag heaps were found by La Touche near the village of Loi Mi (23° 6′, 97° 19′), about 3 miles to the west of Bawdwin. However, he did not find any trace of the ore *in situ*.

Dr. L. L. Fermor has recorded the receipt of specimens of schistose slate and vein quartz with chalcopyrite, chrysocolla and malachite from near Letpandaw (22° 24′ 30″, 96° 23′) in the Möng Lông state.

Southern Shan States.—Malachite is worked, according to Jones, at Kyawk Htap (20° 51′, 96° 49′), and is said to yield 5 viss (about 18 lbs.) of copper to two baskets of ore. However, Jones did not visit the locality. Copper ore is also said to occur at Taunglebyin (20° 40′, 96° 29′).

According to Middlemiss, antimonial tetrahedrite with azurite and malachite occur at a number of isolated places round Yataung hill (20° 57′, 96° 38′), 4 miles to the north-east by north of Myinkyardo. Surface workings were being carried on at Ganaingya, 1¼ miles to the north. The ore occurs in limestone, in thin veins coinciding with the bedding planes. Copper ore is said also to occur 4 miles to the west-north-west of Magwe (20° 38′, 96° 36′) and in the stream beds near Kywemasa (20° 93′, 96° 32′).

About one mile south-east of Ala-*chaung* (21° 0′, 96° 33′ 30″), the rocks bear stains and thin coatings of copper ore. Similarly, films of malachite and azurite are seen encrusting fragments of shale and vein-quartz, according to J. Coggin Brown, on the lower slopes of the western flanks of the Heho range, about 150 feet above the Heho plain, in the first valley north of the one through which the railway from Kalaw to Shwneyaung passes. An unprotected shaft, 30 or 40 feet deep, and the dumps from two or three collapsed adits, are still visible. Similarly, copper staining and pockets and strings of malachite are frequently met with in the gold-bearing rocks, on the western slopes of the Mwedaw hill-mass (20° 39′, 96° 28′ 30″), which lies to the west of Kalaw; but the true disposition and extent of the rock is not known.[1]

Myitkyina District.—Copper ore was extracted during the years 1910 and 1911 from the Taungbalaung reserve, west of the first defile of the Irrawaddy in the extreme south of the Myitkyina district. The output during these two years was 290 tons and 159 tons respectively. Nothing is known of the geology of this locality.

Lower Chindwin District.—The copper ores, malachite and chalcanthite, were found by C. T. Barber[2] to occur locally as vein minerals in the rhyolitic agglomerates and tuffs in the Letpandaung hills in the Lower Chindwin district; but the extensive workings which were opened by Messrs. Jamal Brothers to exploit these ores have now been abandoned. It is believed that the proportion of the ore to matrix is too small for profitable exploitation. It is considered that the tuffs and agglomerates, in which these ores occur, have undergone considerable hydrothermal or metasomatic changes, and it is probable that the introduction of the ores is intimately connected with these phenomena.

Similar veins and impregnations of copper ores occur in the volcanic rocks of "Hill 937," west of Monywa, which is 4 miles north-west of the one described above. This deposit also was opened by Messrs. Jamal Brothers, but the workings have been abandoned.

[1] *Rec. Geol. Surv. Ind.* vol. lxvii, 1933, p. 32.

[2] *Rec. Geol. Surv. Ind.* vol. lx, 1927, pp. 27-28.

Sagaing District.—Traces of copper carbonate are mentioned by Oldham as occurring at Yega (21° 59′, 95° 59′) in a hornblendic slaty rock at the contact with a coarsely crystalline igneous dyke. The yield is alleged to be 5 per cent. of copper.

Salween District.—A specimen of copper ore obtained by O'Riley from a locality on the Yunzalin river was analysed by Waldie and described under the name of O'Rileyite. The principal constituents of the average of the two samples were:

Fe	- - -	39·29 per cent.
Cu	- - -	14·56 „ „
As	- - -	35·57 „ „

One of the specimens contained 0·096 per cent. of silver.

Two localities for copper ore are said to occur on the western side of the Yunzalin river, not far above its junction with the Salween (17° 20′, 97° 44′). Theobald has mentioned the discovery by Foley of fragments of green carbonate of copper in the Botaung hills, 90 miles north-north-east of Moulmein.

Amherst District.—Heaps of copper slag were found by O'Riley at Kyeik Myriam, a day's journey from Moulmein, and at two other localities farther to the south. No ore was observed *in situ*, however. Fryar visited a deposit of copper ore on the Megathat (15° 25′, 98° 20′), a tributary of the Ataran river. A vein of ore containing silver, antimony and copper is mentioned by Helfer as occurring in the Pagah range, between the Salween and Ton-khan rivers.

Mergui District.—Copper ore is said by Helfer to be found on Kala Kyauk Island near Mergui, and on Lampi or Sullivan Island (10° 50′, 98° 12′) in quartz veins traversing clay-slate.

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CORUNDUM.

Corundum is found associated with the gem-stones of the Ruby Mines, Katha district, and the Nanyaseik area, Myitkyina district. The Burma Ruby Mines Co., in the process of extracting rubies and other gems used to obtain a certain amount of " gear " or corundum of opaque colour, which was sold as an abrasive.

FIRECLAY.

Near the military cantonment at Moulmein excellent fireclay has been found. It also occurs on the banks of the Gyaing and Ataran rivers, but the exact localities are not stated by O'Riley.

Pakokku District.—According to Mr. Barber, a coarse pottery is made from the Pegu clays at several villages in the Pakokku district, the chief centre being Sathwa (95° 7′, 21° 39′), and in the Lower Chindwin district, the chief centre being Salingyi (95° 5′, 21° 58′). At Sathwa the industry is restricted to the manufacture of small bowls and household utensils, but Salingyi specialises in the production of large " Pegu jars," which are distributed to many parts of Burma.

The wet plastic clay is moulded to the desired shape on a

potter's wheel, and the vessels thus prepared are fired in kilns after a preliminary baking in the sun. Before baking the clay is bluish-grey in colour, but after firing it assumes a rich brick-red tint.

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GLASS SANDS.

The author [1] found pure white, fine quartz sand in unlimited quantities on the coast of some of the islands of the Mergui Archipelago. These sands are generally found in the neighbourhood of the quartzites of the Mergui Series, *e.g.* about 2 miles north of the southern end of Thamihta Island. A sample of sand taken from this locality yielded 97·22 per cent. of silica. Another sample of a slightly yellowish sand was collected from the western coast of King Island, and on analysis yielded 96·62 per cent. of silica.

Besides the sand, absolutely pure deposits of white quartzite or quartzose sandstone belonging to the Mergui Series occur in inexhaustible quantities, and after crushing could also be used for glass-making. It may be noted that the supplies of sand are practically inexhaustible.

Limestone (Moulmein Limestone) of good quality occurs in this area—in fact in the whole of the Tenasserim division. Sand, alkali, limestone or red lead and coal are the raw materials used in most Indian glass-works. All the ingredients, except alkali, are available in the neighbourhood of Mergui in Burma. Alkali, as in the case of the Indian glass industry, will have to be imported ; but Mergui, being a seaport, has some advantages over the inland towns of India, which have to pay railway freight in addition. It is suggested that the white efflorescent alkali salts, so commonly associated with the Tertiary rocks of the Dry Zone might be tried in the manufacture of glass.

[1] *Journ. Burma Res. Soc.* vol. xvii, 1927, pp. 135-136.

REFERENCE.

34. Chhibber, H. L., "Geography of South Tenasserim and Mergui Archipelago," *Journ. Burma Res. Soc.* vol. xvii, 1927.

GYPSUM.

Gypsum is known to occur in the Pegu Series in several districts, *e.g.* Thayetmyo, Minbu, Pakokku, Magwe and Myingyan. It is most probably associated with the shallow water marine Pegu rocks of the whole Tertiary belt of Burma, but it does not form deposits sufficiently extensive to be of any economic value.

GRAPHITE.

Myitkyina District.—Graphite-schists with a high content of the mineral were found by the author at the following places in the Myitkyina district[1]: near Lawa Htensa (25° 33′, 96° 49′); Tatbum (25° 36′, 96° 50′); a little east of Mupaw (25° 52′, 96° 53′) and between 'Nphum (25° 45′, 96° 51′) and Warawng (25° 41′, 96° 50′). The "3068 Hill" between Kawri (25° 45′, 96° 51′) and Auche (25° 43′, 96° 50′) is built of similar rocks, but it is doubtful if the mineral occurs in payable quantities there.

Ruby Mines.—Graphite occurs freely disseminated in minute flakes through the crystalline ruby-bearing limestone of the Ruby Mines area. In some places the mineral is concentrated into lenticular bands developed along the contact of the limestone with scapolite-gneiss. Deposits of this nature, occurring at a spot some 4 miles to the south-west of Wabyudaung (22° 52′, 96° 9′), were opened up in about the year 1900 by the Burma Ruby Mines Co., but were found to be deficient, both in quality and quantity. According to La Touche, similar deposits also occur on a ridge, about 5 miles to the north-east of Kyaukgyi, (22° 59′, 96° 9′) to the north of Wabyudaung.

Toungoo District.—Fine specimens of graphite are known to be obtainable on the Kanni river, 20 miles north-east of

[1] *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, p. 61.

Toungoo, where the mineral is said to occur in abundance. However, further details of this occurrence are lacking.

Henzada District.—Besides the numerous small occurrences of graphite-schist in the Negrais and Nummulitic rocks of the Henzada district, two localities, in the opinion of the author, are important and deserve mention. The first is in the main tributary to the Kathu *chaung*, a little over a mile south-west of Wadawkwin. The country-rock is a chlorite-schist, in which both graphite and quartz occur as lenticles. Just above the point where the mineral vein crops out, a small water channel exposes this graphite-bearing schist for some distance. Indeed, graphite seems to be present through an exposed thickness of about 75 feet. The second locality, where graphite in the form of lenticles is found associated with schists, lies a little more than a mile south of Kyibin, a little south-west of the road to Wadawkwin. The section of the schists is exposed in a small stream called Thitya *chaung*, and the hill is known as the Subutk-taung. Much quartz is found associated with the schists, and the incoming of quartz here, as elsewhere, indicates the approach to the aureole of contact metamorphism.

The graphite seems to have originated, at least in the first case, by the contact metamorphism of an impure coal seam in a carbonaceous shale or slate by intrusions of peridotite. Boulders of the graphite-schist and sandstone are found side by side, and there seems to be some quantity of impure graphite which cannot be of great value as it occurs intimately intercalated in chlorite-schist and quartz.

Mergui District.—Piddington in 1847 described a substance resembling coarsely foliated graphite, under the name of "Tremenheerite" which was collected by Tremenheere from the neighbourhood of Therabwin (12° 18′, 99° 3′) on the Great Tenasserim river, where it is said to be abundant. On analysis the substance proved to contain 85·7 per cent. of carbon. The best specimens came from the Tagu stream, about 5 miles above Therabwin.

Yamethin District.—A very small quantity of graphite was observed by B. B. Gupta in a vein intersecting gneissose granite in the stream course 2½ miles east-south-east of Yen, in the Yamethin district of Burma.

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KAOLIN OR POTTERY CLAY.

Shwebo District.—An old and important cottage industry of the Shwebo district is constituted by the pottery works of the villages of Nwenyein, Shwegun and Shwedaik, situated on the western bank of the Irrawaddy river, a mile and a half south of Kyaungmyaung (22° 30′, 95° 57′). Less than a mile west of the river bank, according to V. P. Sondhi,[1] a thick bed of highly tenacious clay occurs interbedded with the Irrawaddian sand-rock, and is exposed for about a mile and a half along its strike, dipping to the east at an angle of 12°. This bed furnishes all the clay required, and the industry being very old, large numbers of tunnels and excavations are visible along the exposure. The Pegu jars manufactured here are well-known over Burma and find a ready market even as far as the Delta districts. The industry seems to yield a good return to the villagers and supports the entire population for the greater part of the year.

Lower Chindwin District.—A large lenticle of tenacious clay, enclosed in the Irrawaddian Series, just to the east of Yedwet (95° 11′, 22° 32′), in the Lower Chindwin district, is used extensively in the manufacture of brick-red earthenware which finds a considerable local market.

The "white sand" or "white bed" at the base of the Irrawaddy Series was examined in detail in the Pakokku for kaolin. In this district the bed is said to extend for a distance of nearly 40 miles, and is reported to contain some 25 to 30 per cent. of kaolin. Plasticity and refractory tests have indicated that the clay is of good quality. This deposit is capable of exploitation on a commercial scale. The thickness varies from 15 to 50 feet, and levigation and transport are quite

[1] *Rec. Geol. Surv. Ind.* vol. lx.

easy. This deposit was worked at a locality between Okkan and Kabuak (21° 36′, 95° 5′) villages.

Yamethin District.—Some 8 to 10 miles west of the town of Yamethin a bed of grey to white pipe-clay extends for several miles southwards as far as the village of Thayetpin (20° 20′, 96° 6′).

The kaolin deposits at Yennyein in the Thaton district have been derived from a tourmaline-muscovite-pegmatite or granite. The clay contains about 52 per cent. of free silica and 35 to 36 per cent of alumina. This is good quality kaolin which is capable of exploitation commercially; but the cost of mining, washing and transporting may be a little high.

Henzada District.—Some of the upper beds of the Nummulitic Group, according to Theobald, consist mainly of china clay, almost free from iron. A sample from Indaingon (17° 59′, 95° 10′) was found by Tween to contain 76 per cent. of kaolin and 23·4 per cent. of silica.

Mergui District.—Helfer states that there is a considerable occurrence of kaolin on the bank of the Tenasserim river, four marches above Tenasserim (12° 5′, 99° 3′).

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MANGANESE.

No deposits of manganese of any size occur in Burma, though the mineral has been reported from several districts. It is a common associate of iron, forming the ferruginous concretions so commonly found in the Irrawaddian and sometimes in the Pegu Series. The author confirmed this while working in the Myingyan district. Similarly, Romanis has reported the occurrence of concretions of manganese oxide, probably from the Irrawaddian Series, in the neighbourhood of Yenangyaung (20° 28′, 94° 54′).

Toungoo District.—According to Theobald, the nodular iron-ore characteristic of the uppermost bed of the "Fossil Wood Group" in eastern Prome is represented in Toungoo by tabular masses and irregular nodules of manganese ore, on the low range of hills dividing the Yayuay and Sein Kyaung from the Sittang river. A sample analysed by Tween yielded 28 per cent. of manganese oxide. The grey oxide of manganese has been reported from the Amherst district.

Mergui District.—Manganese ore is reported by Mason and others to occur on some of the islands of the Mergui Archipelago, especially on Gna Islet, Padaw Bay, King Island (12° 29′, 98° 25′). Specimens of tinstone collected by Hughes[1] at Kamong, near Maliwuen (10° 14′, 98° 39′) were found on assay to contain a large proportion of manganese, present in admixed wolfram.

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MICA.

Putao Subdivision, Myitkyina District.—During 1932 prospecting for mica was carried out by J. T. O. Barnard in the Putao subdivision of the Myitkyina district.[2] The pegmatites

[1] *Rec. Geol. Surv. Ind.* vol. xxiv, 18, p. 35.

[2] *Rec. Geol. Surv. Ind.* vol. lxvii, 1933, p. 36.

that carry the mica appear to be associated with the granite mass mapped by Stuart, about 10 miles due east of Fort Hertz. In the course of prospecting, Barnard collected about 11 lbs. of mica of saleable, though low, grade. Big "books" of mica do occur, but those found up to now have all been very much stained and are of no economic value.

Kamaing Subdivision, Myitkyina District.—Mica, mainly colourless, but in places showing a brownish tinge, was found by the author [1] in some quantity on the north-eastern slopes of the Bumraung Bum, about the level of the 1250-ft. contour, *i.e.* just above the pass between the small hill, about $1\frac{3}{4}$ miles north-west of Hkumgahtaung (25° 31′ 42″, 96° 36′ 3″) and the Bumraung Bum (2,476 feet) in the Kamaing subdivision of the Myitkyina district. Books of mica, about half-an-inch thick, and with a diameter of over 4 inches were seen widely scattered on the weathered surface on the left bank of a stream flowing north-north-east and forming the headwaters of the Noidaw *hka*. It is associated in a medium-grained pegmatite with a micrographic intergrowth of quartz and felspar. The author had a small pit dug to a depth of about 6 feet, and found that mica continued to that depth; some of the books measured more than a foot in diameter. Specimens of muscovite, apparently derived from the neighbouring granite hills, were also collected by the author from the Kathan *hka* near Sakaw (25° 29′ 53″, 96° 38′ 43″).

Katha and Mandalay Districts.—Mica occurs near Nweyon in the Mandalay district and near Chaunggyi in the Ruby Mines area, Katha district. In all cases the mineral occurs in granite-pegmatite traversing the crystalline complex of gneiss, granite, chloritic and micaceous schists and marble. The mica of Nweyon is amber-coloured, while that of the other occurrences is either white, green or dark-coloured. The mineral does not occur in large books or in sufficient quantity to warrant commercial exploitation.

REFERENCE.

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[1] *Rec. Geol. Surv. Ind.* vol. lxiii, 1930, p. 47.

MOLYBDENUM.

Molybdenite is found associated with the tin- and wolfram-bearing rocks of Tenasserim, and occurs in granites which have undergone alteration in the neighbourhood of pegmatites, in greisens, and in veins carrying wolfram, cassiterite or pyrites. In veins it occurs close to the walls and is often intergrown with mica. It occurs at the Sonsin Mine, Wagon North Mine, Kadan taung, near Thingandon, Widnes Mine, and the Zimba Mine. Though the mineral is not known to occur at other localities, yet its existence throughout the tin-wolfram belt is likely. The occurrence of the mineral in only small quantities renders practically all these localities of little commercial value except where it may easily be mined in conjunction with wolfram.

REFERENCE.

50. Bleeck, A. W. G., "On some Occurrences of Wolframite Lodes and Deposits in the Tavoy District in Lower Burma," *Rec. Geol. Surv. Ind.* vol. xliii, 1913, p. 68.

MONAZITE.

H. C. Jones reported that the heavy concentrates obtained by panning and washing the sand in one of the streams flowing past the village of Wan Hapalam (21° 32′, 97° 28′) in the Southern Shan States contain considerable quantities of monazite, which occurs as small yellow-green grains, many showing crystalline faces and having sharp edges, showing that they have not travelled far. In the Tavoy district the alluvial sands of the Kyanchaung, which are dredged for tin at Taungthonlon, and the deposits in the Heinze basin are stated to contain some monazite. In the Mergui district Dr. A. M. Heron records monazite as occurring in the Shwe Du and Lamaupyinchaung, but in such small quantities that the deposit is of little commercial importance.

NICKEL.

Some of the pyrites specimens said to have been obtained from the Henzada district contain nickel. The speiss found during the smelting of the lead-silver ores at Nam-tu contain a high percentage of this metal.

OCHRE.

Myingyan District.—Yellow ochre is stated to occur at Panbé (20° 50′, 95° 5′). The thickness was found to be variable, while the maximum was 30 feet.

Tavoy District.—Mason states that an extensive bed of red ochre occurs near Ka-lein-aung (14° 22′, 98° 12′) on the Tavoy river. It is also said to occur on the Great Tenasserim river.

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OIL SHALE.

The Upper Tertiary deposits of the Amherst and Mergui districts carry oil-shale. It is in the upper shale division that the oil-shale occurs in the Htichara basin (16° 46′, 98° 28′). There are several beds of oil-shale of varying thickness and richness, but the richest seam, which carries 20 per cent. of crude oil, is about 6 feet in thickness. Several other bands of greater thickness occur, but they contain a lower percentage of oil.

The other two basins, *viz.* the Myawaddy and Phalu, as mentioned above, occur partly in Burma and partly in Siam, and no attempt has yet been made to analyse samples from these two frontier basins.

The results of an analysis of the crude oil obtained from the oil-shale of the Htichara basin, made in the laboratory of the Geological Survey of India, Calcutta, are as follows :

Water at 50° to 170° C.	42·00	per cent.
Oil at 50° to 170° C.	5·00	,, ,,
Oil 170° to 230° C.	0·17	,, ,,
Oil 230° to 270° C.	1·50	,, ,,
Oil above 270° C.	41·00	,, ,,
Residue non-volatile at 400° C.	10·33	,, ,,

In the Mergui district oil-shales have been met with in a small outlier of Tertiary rocks near Theinkaren village. The

outlier is of small extent, and the occurrence is not perhaps of much commercial importance.

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PLATINUM.

Myitkyina District.—Small quantities of platinum were obtained yearly by the Burma Gold Dredging Co. from the gravels of the Irrawaddy above Myitkyina. During the years 1911–1915 the company won 206·39 oz. of the metal.

Platinum in small quantities, as reported by the author [1] occurs associated with alluvial gold at the various localities mentioned by him (see chapter on " Gold ") in the valley of the Uru river. It is doubtful whether the local inhabitants realise the value of the metal, for, after picking out the gold, the rest of the concentrate is thrown away.

Hukawng Valley.—Hannay stated that platinum occurs in appreciable quantities in the auriferous sands of the Hukawng valley. The author had the opportunity of confirming this claim during his examination of the valley in 1930. Platinum was observed at almost all localities where gold was found, but in very small quantities.

Katha District.—A specimen of gold ore from the Meza river (24° 8′, 96° 4′) was found by Romanis to contain 2·53 per cent. of platinum and 7·04 per cent. of iridosmine.

Lower Chindwin District.—In 1831 Prinsep published the analysis of an alloy obtained by melting together metallic grains associated with gold dust from the Chindwin river. The alloy contained 25 per cent. of platinum and 40 per cent. of iridosmine, the remainder consisting of gold, iron, arsenic and lead. It is said to be brought into the district by the streams flowing westwards into the Chindwin river near Kani (22° 27′,

[1] *Rec. Geol. Surv. Ind.* vol. lxii, 1929, p. 61.

94° 23′) ; and that it contains 20 per cent. of platinum with about twice that quantity of iridosmine.

Tavoy District.—Minute quantities of platinum were detected by Oldham in stream-tin concentrates brought from the neighbourhood of the Heinzé basin by O'Riley.

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61. Bion, H. S., " The Gold-bearing Alluvium of the Chindwin River and Tributaries," *Rec. Geol. Surv. Ind.*, vol. xliii, 1913, p. 246.

SALTPETRE.

During the days of the Burmese kings saltpetre was manufactured at several localities in the Shwebo district. Small amounts of this salt were obtained some time ago from the nitrate-impregnated earth gathered from the stalagmite floors of caverns near Nam-Tok (19° 59′, 97° 1′) in the Southern Shan States.

Yamethin District.—The sandy soil from the foot of the hillock, 3 furlongs west of Sagyin, in the Yamethin district, contains potassium nitrate. It is stated that it appears on the surface as an efflorescence in certain seasons of the year. It is alleged to have been extracted from the soil and used during the Burmese war in the manufacture of gunpowder.

" SOAP-SAND " AND " SOAP-WATER."

The " soap-sand " or " sapaya," as it is locally called, is an impure efflorescent deposit containing salts of sodium, including

the carbonate, with a large amount of intermixed sand. The deposit occurs mainly in the Tertiary rocks of the Dry Zone, and is used for cleaning and washing utensils, laundering clothes, and also by silk merchants for rinsing purposes.

Myitkyina District.—Springs highly charged with alkalies were observed by the author to occur in the bed of the Sapya *hka*, especially near its junction with the Hwehka *hka* in the Kamaing subdivision of the Myitkyina district.[1] The water is used locally to launder clothes. The alkalies have probably been derived from the felspars of the granodiorite exposed immediately to the west.

Shwebo District.—The slushy mud and water which ooze from the mud springs east of Kin-U (22° 46′, 95° 37′ 23″) in the Shwebo district, according to Sondhi,[2] are impregnated with alkali salts, and these are deposited on evaporation. These and the efflorescent salts that encrust the surrounding surface are collected and are refined by evaporating their filtered solutions. The refined product is obtained either in semi-crystalline cakes or in powder, which is locally used for toilet purposes ; the unrefined salt is used to launder clothes.

Lower Chindwin District.—About a mile east of Yedwet (22° 32′, 95° 11′), in the Lower Chindwin district, water highly charged with alkaline salts issues from the ground over a large area and forms a small stream running westwards. The water is allowed to spread over a flat tract to evaporate, and so yields its load of soluble mineral matter, which is used for laundering clothes.

Sagaing District.—Similarly " sapaya " or soap-sand, according to E. J. Bradshaw, is of frequent occurrence in parts of the Sagaing district,[3] but it is not commercially exploited to any considerable extent. In the Padu area, the local inhabitants collect and sell it, especially in years of poor harvest. During 1926 a little less than 300 tons of soap-sand, valued at Rs. 2,691, was produced in the whole of the Sagaing district.

" Sapaya " also occurs in the other districts of the Dry Zone, *e.g.*, in the Wundwin township of the Meiktila district.

[1] *Rec. Geol. Surv. Ind.* vol. lxiii, 1930, p. 54.

[2] *Rec. Geol. Surv. Ind.* vol. lxiii, 1930, p. 54.

[3] *Rec. Geol. Surv. Ind.* vol. lxii, 1929, p. 67.

STEATITE.

Steatite occurs in many places in Burma in association with the serpentinised peridotites of the Arakan-Naga region and of the Myitkyina district.

Kyaukpyu District.—The steatite mines between three and four marches (about 30 miles) to the west of Hpa-aing (20° 15′, 94° 23′) have been described in detail by Hayden. The steatite occurs in thin veins, measuring 8 or 9 inches in width in places. They ramify through dark green serpentine and thin out or disappear abruptly. A sample from this locality tested by Mallet, was compact, of good quality, pale green in colour and cut freely.

Mallet records the occurrence of steatite mines at Myinagade Hill in this district. A sample was similar in quality to that from the mines west of Hpa-aing, but was contaminated with ferruginous impurities.

Sandoway District.—Theobald has described the occurrence of steatite on a low hill, about 3 miles to the north-west of Sandoway (18° 28′, 94° 24′), in veins of fibrous quartz traversing shales and conglomerates. A small quantity of the mineral had been extracted, but only small pieces of the fine quality used for writing purposes could be obtained.

Minbu District.—Hayden has recorded the occurrence of steatite in serpentine near Senlau (19° 54′, 94° 23′ 30″). It is here procurable in blocks half a cubic foot in size, and is said to be of good quality.

Yamethin District.—Steatite occurs in small quantity in the limestone on the hill 2 miles east of Taungbotha, in the Yamethin district. The quantity so far obtained is not promising from an economic point of view.

Prome District.—Steatite has also been recorded from the Shinbaian Hill (18° 57′, 94° 56′) where it is stated to occur in regular layers from 6 inches to a foot in thickness, or in nodules enclosed in a matrix of fibrous quartz.

Henzada and Bassein Districts.—Similarly light green steatite was noted by the author [1] to occur with the serpentine-peridotites of the Henzada and Bassein districts. It was used by Burmans for writing purposes.

[1] *Journ. Burma Res. Soc.* vol. xvi, 1927, p. 197.

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SULPHUR.

It appears that before the annexation of Upper Burma sulphur was extracted in large quantities at several places from the nodules of pyrites found in the blue clay of the Tertiary formations. The principal centre of the industry is said to have been Mawson, in the Southern Shan States. Native sulphur deposits and springs containing sulphuretted hydrogen occur north of Kyin, in the Pakkoku district. These are regarded as of no economic importance. Springs charged with hydrogen sulphide occur at several places in Burma.

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CHAPTER XIV

SOILS.[1]

PEDOLOGY is now a science with a literature and terminology of its own, but in Burma the subject is only beginning to be studied.

The earliest publication on the subject is a short paper by Dr. R. Romanis in 1881. He extracted two soils from Syriam with boiling hydrochloric acid, and analysed the extracts for iron, aluminium, calcium, magnesium, potassium, sodium, soluble silica, phosphoric acid and sulphuric acid. The yield of paddy was found to be roughly proportional to the phosphoric acid in the acid extract. The work was intended to find some scientific basis on which to classify soils for assessment of revenue.

An agricultural chemist was appointed in 1907, and since that date many similar analyses of soils have been made from various parts of Burma. These analyses generally give information regarding the fertility of the soils.

Factors influencing Soil Formation.—Until recently it was the universal practice of investigators to classify the soils in terms of their geological origin or their textural composition. Dokuchaiev, however, discovered that the Chernozem soil type occurred on the most diverse types of rocks in regions of similar climate and vegetation in Russia. As a result of this discovery there arose a tendency in pedological work to ignore the influence of the geological parent material on soil formation, but it is now generally realised that the formation of soil depends essentially on climate, vegetation and geology, and that one or other of these factors may predominate according to conditions. The soils of most parts of the world have been classified on the

[1] This chapter has been written in conjunction with Mr. S. P. Aiyar of Burma Agricultural Service, to whom the author is grateful for his collaboration. He is now engaged in research work at the Rothamsted Experimental Station, Harpenden, England.

basis of their climatic history and group characteristics—thus, we have the following soil groups: Chernozem, podsol, laterite, red earths, desert soils, alkaline soils, etc. The least known soils are those of Asia with the exception perhaps of those of Siberia.

The chief considerations involved in a classification of soils are: (1) the rainfall, (2) the prevailing temperature, (3) topography, (4) the nature of the geological parent material, and (5) the vegetation. There is very little published information on the soils of Burma from these standpoints. However, there are striking climatic factors characteristic of the several natural regions of Burma. The classification attempted here can, however, neither be exhaustive nor very detailed.

The effects of rainfall are leaching, hydrolysis and denudation, and the effects of temperature are to modify the speed of action of water and to cause evaporation or freezing. Topography controls the rate of movement of water and thereby modifies the leaching and denudation processes as well as oxidation and reduction in the soil.

The influence of vegetation on soil formation is also important. Under a cover of grass the organic matter from the roots and leaves accumulates and acid conditions followed by leaching will result. With a forest cover the leaf-fall which accumulates on the surface undergoes decomposition or becomes converted into acid humus. Deciduous tree leaves are rich in bases and therefore they do not induce acidity.

The influence of the parent material on soil formation is rather difficult to define precisely. The two chief types of soil in Burma are: (1) residual and (2) alluvial. A residual soil is developed by the weathering of the underlying rock. Residual soils are, in many cases, very old and have therefore been thoroughly weathered, *i.e.* oxidised and leached. If the original rock is a granite it may give rise to loams and sandy loams, and if the granite is poor in quartz the resulting soil may be a silt or clay. Soils developed from limestones are generally clays or loams with characteristic red or yellow colours as, for example, in the Shan States. Alluvial materials may give rise to gravelly and sandy soils, near the source of a river, and loams or heavy soils in the flood plain area and in the delta.

Soils in relation to Geological Formations.—It may be stated that, on the whole, the nature of the geological parent material influences the texture of the soil to the greatest extent. If the soil is young the effect of the composition of the parent material will be prominent, but as the soil reaches maturity or full development under the prevailing climatic conditions the effect of the geological formations will be more or less obliterated. Below is given a brief geological and mineralogical description of the main types of soils yielded by important geological formations of Burma :

Gneiss and mica-schists : Bright red, often micaceous and sandy.
Chaung Magyi Series : Variegated, clayey soil, of light colours, white, buff, yellow, or pink.
Mergui Series : Heavy brownish red, clayey soil.
Naungkangyi beds : Variegated clays, mainly yellow, sometimes orange-red or reddish-brown.
Hwe Maung beds : Lavender or lilac clays when dry, becoming purple when moist.
Lower Namhsim Series : Brown and generally sandy soil.
Upper Namhsim Series : White or buff, clayey soil.
Plateau Limestone : Bright red clays. The Permo-Carboniferous rock yields blue-grey or yellow soil.
Namyau beds : Violet red or dark purple sandy soil, occasionally clayey.
Axial Series : Clayey soil.
Negrais Series : Variable loamy to a clayey soil.
Serpentines : Bright red, ferruginous, scanty, clayey soils.
Granites : Light sandy soils.
Eocene : Heavy clayey soil, loamy or sandy in places.
Pegu Series : Variable loamy soils with patches of clayey soils.
Irrawaddian Series : A very light sandy soil, sometimes loamy, with patches of clay.

In the sequel are discussed the chief characteristics and the mode of formation of the soils of the important geological formations which occupy considerable extents in Burma.

Archaean Gneiss, etc., Soil.—The Archaean gneisses, etc.,

yield a very light sandy soil. On the steep slopes, however, all soil is washed away, leaving not infrequently bare rock masses.

Plateau Limestone Soils.—The soil of the Plateau Limestone, which is generally a bright red clay, furnishes a typical example of the residual soils. The colour is a bright Indian red, sometimes with a slight orange tint when dry, but becoming much darker when wet. On the open plateau the clay is devoid of sandy matter and is of a stiff and tenacious character. It contains nodules of iron oxide ranging from the size of a pea to that of a hazel-nut. These nodules are not unlike those which sometimes build up laterite. La Touche is of the opinion that the red clay and laterite are formed by a similar process. In fact, where further concentration of ferric oxide has been possible it has formed iron ores. La Touche compares it with the "Terra Rossa" of South-east Europe, where it is largely developed on the limestone tracts of Istria and Dalmatia. It attains a large thickness, sometimes twenty or thirty feet or even more. This thickness must represent the denudation of an enormous quantity of limestone, for the amount of insoluble matter present in it is very small. However, La Touche is of the opinion that weathering of the bands of clay, interbedded with the limestone, must have largely contributed to its formation.

Unfortunately the red clay forms a sterile soil so far as the growth of cereals is concerned. This sterility may well be in some measure due to the absence of lime, and La Touche has suggested that the effects of the addition of lime should be experimented upon.

According to Stamp a modification of this dark red, very ferruginous, clayey soil occurs when the drainage of the area is good and much humus has collected, producing a dark rich loamy soil which is very productive indeed.

Sometimes, especially when the limestone forms steep-sided hills and ridges, there is very little soil to be seen, and the trees root in the cracks in the limestone and numerous crags are seen everywhere.

Axial and Negrais Soils, Arakan Yoma.—In the Arakan Yoma the Axial and the Negrais Series, consisting of hardened

shales with sandstones, form its major portion. The harder rocks yield a very stony soil, made richer by humus in the valleys.

Serpentine Soil.—The serpentines and altered peridotitic rocks form fairly large tracts in the Arakan-Naga region and also in the north. They invariably form a bright red clayey soil. This bright red colour is so characteristic of the serpentine soil that the writer has often used it as a very helpful adjunct in his geological mapping. The soil is invariably sterile and yields a very poor and specialised type of vegetation. For further details regarding the ecology of the soils reference may be made to the author's paper on the serpentines of the Henzada and Bassein districts.[1]

Mergui Series Soils.—The Tenasserim Division, as remarked already, is mainly built of the Mergui Series, into which granite has been intruded. The soil of the Mergui Series in the Tavoy district is a brownish clay which covers the formation everywhere except where granite is the underlying formation. The conditions governing atmospheric weathering are the most favourable in this region, with luxuriant vegetation and excessive rainfall. According to Drs. Coggin Brown and A. M. Heron, decomposition has penetrated to a remarkable depth below the surface, so much so that only a few exploration adits have reached fresh rock. The first stage in the formation of soil is the oxidation of the ferrous constituent to hydrous ferric oxides, and the opening of the close and irregular joint-planes, so that a red or brown rock is produced, still hard, but it breaks into splinters. Passing upwards, this is seen to soften and lose coherence until it becomes a compact lithomarge, mottled in shades of brown, red and purple. Its thickness varies considerably, depending on the slope of the ground, being thin or absent on steep hill-sides and thick on flat land. It, again, is further broken up by superficial creep and the disintegrating action of tree roots, graduating with a certain amount of organic vegetable matter into the red clayey soil of the surface. Farther south, in the Mergui district, the rocks being more arenaceous, the soil becomes also slightly more sandy, but the general product again is variously coloured clays, from

[1] *Journ. Burma Res, Soc.* vol. xvi, 1926, p. 178.

buff-yellow to brownish-red, according to the proportion of iron and the degree of decomposition they have undergone. However, the interbedded sandstones crumble on weathering to white sand. When worn down to sea-level the Mergui Series gives rise to low islands surrounded by mangrove and other swamp forests.

Granite Soils.—The surface soil of the granite is much lighter in colour and more sandy than that formed from the Merguis. Where the weathered material is not readily removed the granite is thoroughly decomposed, in places, to a depth of as much as a hundred feet, becoming soft and reddish-yellow from the decay of felspars and biotite, with the liberation of iron oxides and hydrous aluminous silicates. When unprotected by forests the heavy rains may easily wash away whole hillsides, exposing the bare granite. When protected from the destructive action of rain the soil may become rich in humus, and supports high evergreen forests. Such granitic soils are often rich in plant foods, especially potash.

In the extreme north of Burma the following sections were observed in the granite or granitic gneiss, composing hills about 2,500 feet above sea-level. Distances are given in feet from the surface, and the depth of the decomposed gneiss is given as far as observed:

1.	Soil.	5 feet 4 inches.
	Subsoil.	9 feet 2 inches.
	Decomposed rock.	Dug to 13 feet 6 inches.
2.	Soil.	7 feet 6 inches.
	Subsoil.	15 feet 2 inches.
	Altered gneiss.	Dug to 28 feet.
3.	Soil.	12 feet 8 inches.
	Subsoil.	20 feet 10 inches.
	Decomposed gneiss.	Dug to 31 feet 4 inches.
4.	Soil.	9 feet 2 inches.
	Subsoil with patches of decomposed rock.	18 feet 4 inches.
	Decomposed rock mixed with subsoil.	22 feet.
	Decomposed rock.	Dug to 28 feet.

Pegu Soils.—The Central Belt of Burma, as shown above, is composed of Tertiary rocks which are built mainly of sandstones with shales and occasional bands of limestone. The Pegu Series, consisting generally of alternating sandstones and shales, yield on the whole good loamy soils with local variations. This is the most common soil in the north of the Pegu Yoma, where folding is complex and the beds are much mixed. Where the formation consists mostly of shales it gives rise to a stiff clay. Dr. Stamp cites the Kodugwe valley east of Letpadan as an example, and says that this type of soil is common from Prome to Insein. Farther south, in the wetter southern parts of the Pegu Yoma, true cellular lateritic soil is developed in places.

Irrawaddian Soils.—The Irrawaddy Series yields a very poor, coarse, sandy soil, varying in nature from sand to sandy loam with very occasional patches of clay. The soils are sometimes ferruginous and gravelly and tend to form " hard pans." In the drier parts they form well-known large stretches of barren, broken ground.

It has been noted above that the Tertiary rocks and their resultant soils are more sandy in the north than in the south. Generally speaking, the soils of the Tertiary rocks can be classified into : (1) clays and clayey loams, (2) loams, (3) sandy loams, (4) sands, (5) gravels and rocky soils.

The Arakan coastal strip consists of folded and hardened Tertiary rocks. These do not differ greatly from those of the Pegu Yoma, but are generally more hardened, and so, instead of forming good loamy soils, form very poor stony soils. Sometimes the accumulation of good soil is also hindered by the heavy rainfall.

Mention may be made of large stretches of red, ferruginous Plateau Gravel, especially capping the low cliffs on either side of the Irrawaddy.

The soils of volcanic rocks, *e.g.* those of Mount Popa, the Lower Chindwin, Wuntho, etc., are very fertile, so much so that the writer found the craters and the sides of these hills very fully cultivated. In places there appears to be very little soil, yet the plants were often seen growing well in very stony soil.

Finally, the deltas, and especially the lower portions of the valleys of the Irrawaddy and the Sittang, form the rich treasure-

land of Burma. These famous paddy lands are composed of alluvium which is mostly a heavy loam. As in the Pegu district the low-lying land is generally of a heavier texture than the higher land, and is richest where the subsoil is clay and the surface is loam or silt and clay. Tracts liable to inundation by rivers are generally covered by rich silt deposits. However, they show minor variations in physical and chemical characteristics from district to district. Similar stretches of alluvial soils occur in the flat course of almost all the important streams of Upper Burma.

General Features of the Soil Zones.

The soils of Burma may be grouped into four main zones: (1) the soils of the Delta and the Coastal strips; (2) the soils of the Dry Zone; (3) the soils of the Shan Plateau, and (4) the soils of the Northern Hills region.

The word "zone" is used here in a very limited sense. In contrast with its dominant effects in the great plains of Europe, the U.S.S.R. and U.S.A., the effect of climate has not yet produced a clearly defined zonal differentiation in the case of Burma. This is a small country with an extremely varied topography. Here, as in the British Isles, the soils are generally immature and the effects of geology important. The climatic features of the four zones are, however, strikingly different.

(1) **The Delta and the Coastal Strips.**—This region receives a high rainfall, about 80–200 inches a year. The prevailing temperatures are high throughout the year, averaging about 80°–85° F. The difference between the hot and the cold weather temperatures is small. In its topography the Delta is very low-lying and almost level. In the Delta the soils are alluvial in origin, consisting of sediments brought down by the Irrawaddy and other rivers.

The coastal strips are also rather low, but they receive a much higher rainfall than the Delta region. Land is therefore subject to heavy erosion in the coastal strips. On the Arakan coast the soil seems to be alluvial, being derived from the washings carried by rain from the Arakan Yoma. On the Tenasserim coastal strip similar conditions prevail.

(2) **The Dry Zone.**—This region is situated in the centre of Burma, and the rainfall is low, about 10–40 inches. The summer temperatures are the highest in the country, but in winter the temperature is quite moderate. The difference is very large. The actual summer temperatures vary between 80° and 100° F., and the winter temperatures from 65° to 75°. During summer a strong wind blows from the south. The topography is generally level and the drainage is poor. The accumulated water during rains does not sink into the soil, as it is rather impervious, but dries up by evaporation caused by sun and wind.

(3) **The Shan Plateau.**—This is a tableland about 3,000 ft. or more above sea-level. It is very mountainous, with a few valleys, to which the agricultural soils are confined. This zone receives a moderate rainfall of 40–60 inches. The summer temperature averages about 75°. The soils are generally residual, although in the valleys transported soils occur.

(4) **The Northern Hills Region.**—This area is situated in the extreme north of Burma and receives a fairly high annual rainfall, about 60–80 inches. The summer temperatures are about 80°–85°, and the winter temperatures about 60°–70°. The area is hilly and undulating. Most of the soil-forming materials are alluvial (bench land) and in places residual. This region has not been much explored agriculturally.

Mechanical Composition of Soils.

As pointed out previously the influence of the parent material is greatest in the mechanical composition of the soils. Alluvial materials are of three grades: (1) those of alluvial fans, near the sources of rivers are usually gravelly and stony; (2) bench land or terrace land is rather sandy near the river, but the flood plain soil is of fine texture; (3) delta deposits are of fine texture.

The table on page 256 shows the percentage mechanical composition of soils from the places named in the different zones.

Chemical Characteristics of Burma Soils.

The more important criteria for the classification of soils are: (1) the percentage of humus; (2) the colour; (3) the degree of leaching as reflected in the percentage of lime; (4) the accumulation and distribution of carbonates, particularly

	Stones and Gravel.	Coarse Sand.	Fine Sand.	Silt.	Fine Silt.	Clay.
Delta Zone.						
Pyuntaza - -	—	2·0	21·6	23·0	38·8	14·6
Thanatpin - -	—	9·4	36·1	28·6	18·5	7·4
Kadok - - -	—	1·8	9·5	10·7	38·5	39·5
Kyauktan - -	0·6	0·1	9·6	43·0	33·5	13·2
Hmawbi - - -	—	0·5	9·7	23·5	41·9	15·8
Myaungmya - -	—	7·3	10·0	24·0	46·4	12·3
Coast Strips.						
Mudon - - -	—	5·1	17·9	21·4	33·8	15·9
Akyab - - -	—	48·4	16·1	12·9	13·8	6·6
Kyakpyu - -	—	21·1	9·9	26·7	31·9	10·3
Dry Zone.						
Flood plain and bench lands.						
Mandalay - -	—	4·1	18·2	12·8	16·1	40·2
Padu Black - -	1·6	4·3	7·0	5·8	13·4	56·8
Myitha - - -	—	1·7	22·4	29·6		39·5
Taungbyon, near Mandalay - -	1·4	13·7	20·9	10·7	25·7	26·7
Pyinmana - -	—	9·6	31·0	25·5	16·2	15·9
Pwinbyu - -	—	1·0	12·0	33·4	30·4	18·5
Allanmyo (bench land) - - -	14·2	50·3	12·6	6·1	6·9	8·0
Shan Plateau.						
Taunggyi (Valley)	3·1	5·1	16·0	16·5	36·2	23·1
Upland region, -	No data available, coarse-textured.					
Northern Hills Region.	Coarse or medium-textured.					
Hopin (low valley) -	2·0	43·2	28·3	1·0	10·3	12·8
Sahmaw (red) - -	—	16·2	35·0	16·6	24·8	7·4

These results were obtained by the old A.E.A. method using Robinson's pipette technique.

calcium carbonate ; (5) soil reaction ; (6) the nature of eluviation as measured by the composition of the clay fraction, usually the molecular ratio of silica to sesquioxides in the soil profile ; and (7) the extent of weathering as measured by the distribution of alumina in the clay fraction and in the whole soil.

The examination of a vertical section of a soil or the soil

profile is exceedingly important in determining the development of a soil. Unfortunately neither the profiles nor the clay fractions of Burma soils have yet been examined in any detail.

Many attempts have been made by various authorities to express the effects of climate in the form of a single expression. The most interesting of these attempts is that due to Crowther, who has shown that the formula, $R-3{\cdot}3T$ = leaching factor, expresses the effects of climate on soil formation. The soil zones of the United States of America are closely related to the leaching factor. (R = Rainfall in cms.; T = temp. in degrees Centigrade.) An application to the soil zones of Burma gives interesting results tabulated below:

Area or Zone.	Rainfall in Inches.	Leaching Factor.	*p*H.	CaO.	$\frac{CaO}{MgO}$	C.	N.
Coastal Strips.	Very high rainfall; high temperature.						
Akyab	240 inches	+521	6·5	0·13	0·42	0·64	0·07
Mudon	200 inches	+409	5·1	0·12	0·60	3·30	0·15
Delta Region.	High rainfall; high temperature.						
Myaungmya	100 inches	+165	5·5	0·12	0·36	2·23	0·17
Hmawbi	96 inches	+145	6·1	0·29	1·40	?	0·07
Northern Hills Region.	Fairly high rainfall; medium temperature.						
Hopin	70 inches	+109	6·6	0·40	0·95	0·75	0·08
Sahmaw	72 inches	+ 65	6·3	0·98	0·49	3·0	0·20
Shan Plateau.	Medium rainfall; lowest temperature.						
Taunggyi	60 inches	+84	6·1	0·27	0·90	1·76	0·15
Yawnghwe	40 inches	+31	6·7	0·55	2·20	1·90	0·17
Dry Zone.	Low rainfall; highest temperature.						
Pyinmana	45 inches	+25	6·5	0·83	2·10	0·57	0·07
Allanmyo	40 inches	+11	6·7	0·45	1·80	0·73	0·04
Pwinbyu	30 inches	−13	7·5	—	1·30	0·87	0·11
Mandalay	30 inches	−13	8·0	0·38	1·90	0·42	0·03
Mahlaing	27 inches	−20	8·0	2·04	2·80	0·99	0·09
Padu	30 inches	−23	8·2	—	1·40	0·22	0·03

It is obvious from the table that the leaching factor varies in a regular manner from one group to another, and, moreover, with the chemical data such as *p*H, lime content, organic

carbon (a measure of humus), etc. In the case of the Shan Plateau and the Northern Hills Region the soils referred to are developed in valleys and therefore do not show strikingly different characteristics as expected from the leaching factor. In this connection it may be pointed out that the effect of topography masks the climatic influence to some extent.

The exchangeable bases and base-exchange capacity of soils are important features of soil zones. From the meagre data available, the following conclusions are possible: (1) in the Dry Zone the total exchangeable bases held by the soil and the exchange capacity are the highest. This is to be expected as the soil in this region is not subject to much rainfall or leaching. The percentage of exchange complex in the soil, chiefly aluminosilicates, may also be assumed to be high. This is supported by the fact that the percentage of soluble silica in the soil (after boiling with HCl) is high, about 15 per cent. in Mandalay soil. In this region also there is the very general accumulation of carbonates and alkali salts. (2) In the Shan Plateau the actual amounts of bases held by soils are very low. The soils develop large amounts of exchange acidity and show fairly high lime absorption. Soils of some parts of the Shan Plateau (Hsum-Hsai estate and Thadaung tea estate) are completely devoid of exchangeable lime, but contain large amounts of magnesium. (3) In the Delta Zone the soils contain fair amounts of bases. There is no accumulation of carbonate in the surface soils, but in many places the subsoils seem to be somewhat enriched in carbonates. In places subject to flooding by saline water the soils are rich in exchangeable sodium. (4) There is practically no information available regarding the exchangeable bases in the soils of the Northern Hills Region.

The following data have been compiled from the publications of the Burma Agricultural Department:

Area.	Total Bases[1] (including Carbonates).	Carbonates.[1]
Mandalay District - (Dry Zone)	38 millieqts per cent.	8 millieqts per cent.
Pegu Division - (Delta Zone)	16 ,, ,,	—

[1] Average for agricultural soils.

Distribution Ratio of Exchangeable Bases

Area.	Ca.	Mg.	K.	Na.
Mandalay District (Dry Zone)	61	23	5	10 per cent. of total.
Pegu Division - (Delta Zone)	50	41	2	4 per cent. of total.

Accumulation of Carbonates and Soda in Dry Zone.

Area.	Total Bases, including Carbonates.	Carbonate.	Ca.	Na.
	Millieqts per cent.			
Kyaukse (*a*) -	973	955	684	6
Kyaukse (*b*) -	296	254	270	23
Shwebo - -	507	265	494	12

The Soil Groups of Burma.

It is rather difficult to classify the soils of Burma according to the standard groups. The data required are almost entirely lacking. The classification attempted here is therefore only tentative.

(1) **Laterite.**—An account of the distribution of laterite and its geological relationship is given in Chapter XXXIV of the author's *Geology of Burma*, 1934. No information is available on the profiles or chemical composition (complete analysis) of Burmese laterite.

(2) **Red Earths.**—This group of soils is confined chiefly to the Shan Plateau and certain parts of the Northern Hills Region. The colour of these soils varies from red to pink and brown. Many samples have a *p*H of about 6 in the surface layers, although some are more acid. The more acid samples develop high exchange acidity when treated with a normal solution of potassium chloride, the *p*H becoming 3·5 or less. The lime requirement measured by the method of Hardy and Lewis

is fairly high. A typical profile has the following characteristics :

Red Earth Profile—Sahmaw.—Derived from Peridotite—Serpentine rocks.

Depth.	Description.	pH.	Exchangeable Bases—Milliequivalents per cent.	
			Ca.	Mg.
0– 3in.	Red brown friable -	6·4	5·5	5·4
3in.–12in.	Red brown cracked -	5·9	2·1	3·3
12in.–24in.	Red brown - -	6·2	—	—
24in.–36in.	Red brown transition	6·9	—	—
36in.–72in.	Rotten boulders—clayey - - (No subsoil water.)	7·0	—	—

(3) **Yellow Soils.**—These occur closely associated with the Red Earths. Frequently they have a mottled appearance in the lower layers of the profile. In general they have a uniform bright yellow colour except in the surface layer which is somewhat dark due to humus.

(4) **Soils with Carbonate Accumulation (Black Earths).**—This group of soils occurs in the Dry Zone. The colour of the dry soils varies from black to straw yellow, but becomes much darker on wetting—the parent material is Older Alluvium. The texture of the soils ranges from heavy clays to sandy loams. These soils are all calcareous, the content of calcium carbonate varying from 1 to 13 per cent. The heavier soils are very sticky and tenacious when wet, hence the Burmese name *Sane-putchi* (sticky) for these soils. The stickiness of these soils is somewhat unexpected as they are rich in calcium and magnesium and low in potassium and sodium. Moreover, the percentage of clay is not excessive, 40 to 50 per cent. being the highest. In general the pH value is about 8.

J. Charlton has published a note on the profile of a typical soil of this group. He describes it as a carbonate solontschak.

Black Earth Profile—Mandalay.

Depth.	Stones per cent. 72 mm.	pH.	CO_2 per cent.	Acid soluble CaO per cent.	Acid soluble Na_2O per cent.
0– 2ft.	1·0	8·1	0·2	1·0	0·5
2ft.– 4ft.	4·0	8·4	0·5	1·5	0·8
4ft.– 8ft.	8·0	9·0	1·0	2·5	1·0
8ft.–12ft.	3·0	8·9	0·3	1·5	0·8

Nodules of calcium carbonate (kankar) are present in the subsoil, and are largest in size and most frequent between 4 ft. and 8 ft. The amount of organic carbon in the surface layer is about 1 per cent. The humus layer extends to a depth of 3 ft. Below this the soil is yellow. The high pH in the deeper layers indicates the accumulation of soda. In places where this type of soil is irrigated the exchangeable sodium in the surface layer is about 1·5 milliequivalents and in the subsoil (6 in.–1 ft.) about 2 milliequivalents per 100 grams of soil.

The Black Earth Soils of Burma closely resemble the Black Cotton Soils of India and Africa. The points of resemblance may be enumerated thus: (1) they have a dark **A** horizon; (2) they contain calcium carbonate in the whole profile with concretions in the subsoil; (3) they have a high base status; (4) they show a pH of about 8; (5) they crack badly on drying; (6) they are developed under alternate wet and dry conditions with high temperatures and low or medium rainfall; and (7) they are very sticky when wet.

The Indian Black Cotton Soils are heavy textured, whereas the Burmese type has all grades of texture. Professor G. W. Robinson states (**Soils**, p. 232) that Black Cotton Soils may be developed on light textured materials.

Although these soils show some relationship to the Chernozems they differ from the latter in many respects. The Burmese and the Indian Black Earths have developed under high temperature, contain only small amounts of organic matter, and are very sticky when wet. The Chernozems, on the other hand, have developed under relatively low winter temperatures,

contain high percentages of organic matter, and are extremely crumbly in structure.

The natural vegetation on the Burmese Black Earths consists of scrub plants and thorny bushes. Leguminous plants and trees, as well as cotton and sunflower, thrive extremely well on these soils.

(5) **Saline and Alkaline Soils.**—These soils are found in the Dry Zone in the more arid portions. They are developed from Alluvium which varies in texture from heavy loam to coarse sands. Large accumulations of carbonates and sulphates of sodium, calcium and magnesium occur in various areas. As is to be expected, the *p*H of these soils is 9 or more. Cement foundations exposed to water in these areas suffer ready destruction due to the action of sulphates. The colour of these soils varies from yellow to brown.

In the Sittang valley there are soils containing sodium chloride and large amounts of exchangeable sodium. The salt is derived from the river water which has a large admixture of sea water due to tidal action. There is also another area of saline soils on the coast between Rangoon and Moulmein. This area has been formed by the gradual withdrawal of the sea.

Near the large oil fields at Yenangyaung and Chauk, which are semi-arid regions, there are soils containing gypsum. These soils are rather coarse textured and have the colour of Portland cement.

(6) **Red Loams.**—Vaveler distinguishes between Red Loams and Red Earths and states that the latter are more mature than the former. In Burma the Red Loams are distributed in the Northern Hills Region and also in parts of the Delta and the Coastal Strips. The colour varies from reddish brown to pale brownish yellow. Similar soils occur also in places in the Dry Zone which are semi-arid. In all cases, however, they are situated in elevated areas which allow satisfactory drainage.

(7) **Vlei Soils.** (Soils with impeded drainage).—It is a very common feature in Burma in all the zones to find red and black soils side by side ; the red soils are situated on a higher level and are therefore better drained than the black soils, which have invariably poor drainage owing to their low position.

As noteworthy examples the following places representing each zone are given in the table :

UPLAND.

Locality.	Zone.	Colour.	*p*H.	CaO.	C.	Clay.
Mudon -	Coastal -	Red	5·3	0·04	3·3	21·4
Myaungmya	Delta - -	Red	5·6	0·03	0·79	4·5
Hmawbi -	Delta - -	Red	6·1	0·06	—	—
Pyinmana -	Dry zone -	Red	6·5	0·83	0·57	15·9
Padu - -	Dry zone -	Red	6·2	0·17	0·22	7·7
Yawnghwe -	Shan Plateau	Red	7·1	0·55	1·04	—
Sahmaw -	Northern Hills	Red	6·2	0·98	3·0	7·4

LOWLAND.

Locality.	Zone.	Colour.	*p*H.	CaO.	C.	Clay.
Mudon -	Coastal -	Black	5·5	0·12	1·87	15·9
Myaungmya	Delta - -	Black	5·5	0·12	2·23	12·3
Hmawbi -	Delta - -	Black	6·1	0·04	—	15·8
Pyinmana -	Dry zone -	Black	6·5	1·21	0·74	9·5
Padu - -	Dry zone -	Black	8·2	1·43	0·58	56·8
Yawnghwe -	Shan Plateau	Black	—	4·67	1·9	—
Sahmaw -	Northern Hills	Black	6·5	0·90	1·9	23·2

The effect of leaching the soil is evident when the lime contents of the upland and lowland soils are compared. There is also a tendency for the lowland soil to be heavier, to be slightly more alkaline, and to contain more organic matter than the upland soil. The black colour does not seem to be due to excess of organic matter, *e.g.* Mudon and Sahmaw, where the red soil contains much more organic matter than the black soil. Various other reasons have been suggested, such as the ratio of silica to ferric oxide and alumina, the presence of titaniferous iron-ore or perhaps magnetite, the presence of ferrous sulphide caused by reducing action under bad drainage, etc. Although these reasons might partially account for the black colour of certain soils the true cause of the black colour in a low-lying soil is still unknown. One possible explanation may be the difference in surface area of the soil which is generally large in a clayey soil. The low-lying soils generally contain more clay or silt than the upland soils. This is, however, not universally true. The black

colour may be most probably associated with a high percentage of lime and other bases. The low-lying soils invariably contain larger amount of bases than the upland soils.

The black soils described here have features in common with those of the Vlei Soils of Africa and may therefore be grouped under this name. They are situated in positions with restricted drainage and are subject to alternate wet and dry seasons. The colour of the soils is greyish black, brownish yellow or greyish yellow. As in Burma, the Vlei Soils of Africa are also associated with Red Loams or Red Earths.

Some typical profiles of Burmese Vlei Soils are recorded below:

Profile 1.—*Sahmaw—Vlei type.*—Derived from Peridotite—Serpentine rocks.

70 ins. rainfall.

Depth.	Description.	*p*H.	Exchangeable Ions—Millieqts per cent.	
			Ca.	Mg.
0– 5in.	Black columnar cracked	6·1	4·8	28·4
5in.– 12in.	Black columnar cracked	6·5	3·7	28·8
12in.– 22in.	Yellow putty-like - -	7·0	—	—
22in.– 28in.	Black irregular - -	6·9	—	—
28in.– 38in.	Bluish yellow - -	7·2	—	—
38in.– 50in.	Yellow red streaked -	6·9	—	—
50in.– 62in.	Yellowish blue - -	6·8	—	—
62in.–108in.	Yellowish gritty - -	6·8	—	—
108in.	Subsoil water - -	6·9	—	—

Profile 2—*Vlei type.*—Derived from Peridotite—Serpentine rocks.

Depth.	Description.	*p*H.	Exchangeable Bases—Millieqts per cent.	
			Ca.	Mg.
0– 9in.	Black cracked - -	6·5	5·1	22·8
9in.–19in.	Yellowish black columnar	7·2	2·2	13·4
19in.–31in.	Yellow, vertical black streaks - - -	7·7	—	—
31in.–49in.	Yellow, mottled streaks -	7·6	—	—
49in.–72in.	Yellow mottled red -	8·0	—	—
72in.	Subsoil water - - -	6·4	—	—

Profile 3—*Vlei type.*—Derived from Peridotite—Serpentine rocks.

Depth.	Description.	*p*H.	Exchangeable Bases —Millieqts per cent.	
			Ca.	Mg.
0– 8in.	Black friable - -	6·5	3·7	22·0
8in.–17in.	Black compact cracked	6·8	3·2	5·9
17in.–24in.	Yellow gravelly - -	7·2	—	—
24in.–29in.	Fine gravel - - -	7·2	—	—
29in.–42in.	Yellow grey gritty -	6·9	—	—
42in.–49in.	Grey gritty - - -	7·3	—	—
49in.-80in.	Clayey gravel - -	7·3	—	—
72in.	Subsoil water - -	7·1	—	—

(8) **Immature Alluvial Soils.**—Soils derived from recently deposited allüvium have not had the full play of climatic and other forces of weathering and are therefore immature. The rivers of Burma are liable to flood during the rains and large areas receive a deposit of mud. This is almost an annual feature in the Delta and the tracts through which the Irrawaddy, the Sittang and other rivers flow. On the south coast the sea has receded in places in recent years and soils have been formed from the marine alluvium. These again are immature.

Erosion is another cause of immaturity in certain areas. The valleys in the Shan Plateau, in the Northern Hills Region, the lands bordering on the Arakan and the Pegu Yomas, and in the Tenasserim Region receive deposits of alluvial materials washed down by the torrential rains from the mountain slopes. Even in the Dry Zone where the rainfall is low, several inches of rain may fall during a few hours. The rivers and streams become extremely muddy ; but fortunately they flow relatively slowly so that there is time for partial sedimentation of the mud carried by them.

Erosion occurs to the largest extent on heavy soils as these are also generally impervious. Land on steep slopes is also liable to serious erosion. As a protection against this, a system of terracing the land is in use in Burma. Alkaline soils which contain sodium are very easily eroded. In the Dry Zone the banks of canals, roads, railway embankments and similar

foundations suffer serious damage during rains or floods. The water running through the canals contains sodium bicarbonate in appreciable quantities. Prolonged action converts the soil clay into sodium clay which " melts " away into a porridge-like mass in contact with water.

(9) **Immature Mountain Soils.**—Unlike the valleys, the tops and the sides of mountains are liable to lose their surface soil by erosion. When covered with trees and plants, however, erosion is checked to some extent. Moreover, the fallen leaves which cover the soil serve as a further protection against erosion. In places devoid of tree growth and in areas cleared of their protective covering erosion has full play.

The soils of the Arakan and the Pegu Yomas as well as those of the mountains in the Northern Hills Region and of the Shan Plateau are most probably immature to a large extent. However these mountains are well covered with trees and other vegetation.

Soil Map of Burma.

Krische has published a soil map of the world based on the publications of Glinka and of Prassolov. On this map only two groups of soils are shown in Burma, namely, a podsolic group in the area roughly covered by the Northern Hills Region, and all other parts are shown to be occupied by Tropical Red Earths. Obviously this grouping is very general indeed. It will be rash to construct a soil map of Burma with the meagre information now available. The best plan seems to be to divide the country into its natural regions and to indicate their characteristic soil groups in a general way ; see Fig. 13.

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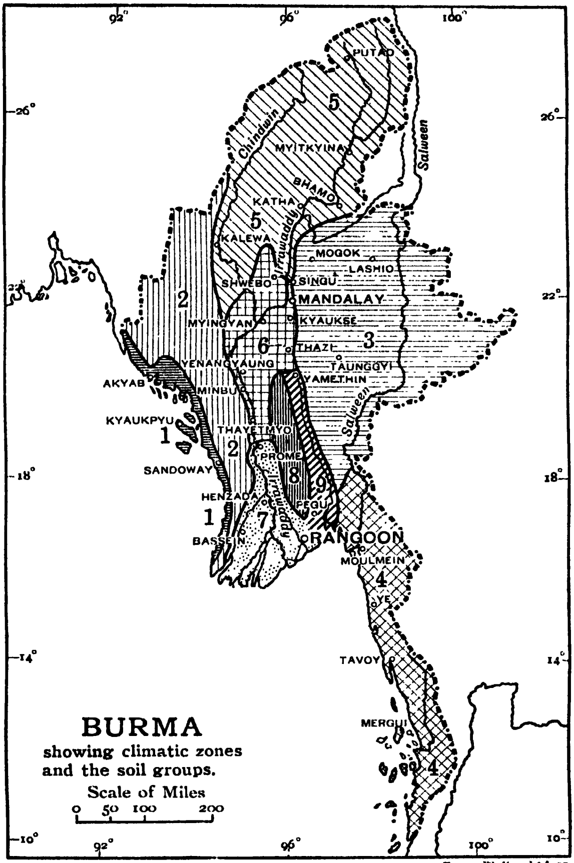

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FIG. 13.

1. Arakan Coastal Strip -	Red Loams—Immature alluvial soils.
2. Western Hills Region -	Mountainous country—Immature alluvial soils.
3. Shan Plateau - -	Red earths and yellow soils—Vlei soils in valleys.
4. Tenasserim Coastal Strip	Red loams—Immature alluvial soils—Laterite in places.
5. Northern Hills Region -	Red earths and Red loams—Vlei soils in valleys.
6. Dry Zone - - -	Black earths—Alkali soils, Saline soils, and Vlei soils.
7. The Delta - - -	Immature alluvial soils—Vlei soils—Laterite in places.
8. The Pegu Yoma - -	Mountainous country—Immature alluvial soils—Red loams.
9. The Sittang Valley -	Immature alluvial soils—Red loams—Vlei soils.

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CHAPTER XV

WATER SUPPLY

RAIN falling on the land forms almost the entire source of the water supply of a tropical and sub-tropical country like Burma. The rain water partly runs off into the streams and lakes ; or evaporates, particularly in the tropical regions ; or is absorbed by vegetation or percolates through the soil into the underlying strata. The proportion of run-off, evaporation, absorption and percolation varies a great deal, depending on the nature of the soil, vegetation, the amount and rate of rainfall, temperature, humidity, altitude and slope of the region.

The water supply of a region may be obtained from surface water or ground water, or from both. The surface water sources are streams, lakes, storage tanks and impounding reservoirs. In Burma almost the whole of the rain falls during the period May to October, while the rest of the year is practically dry. As a result, especially in the Dry Zone, the smaller streams run dry, which makes the problem of water supply in this region most difficult.

In all agricultural countries, *e.g.* Egypt, the Punjab, Burma, U.S.A., which depend on irrigation, impounding reservoirs play an important part. The most favourable site for such a reservoir is found where a river valley forms a comparatively broad level area bounded by steep slopes which converge lower down. The type of dam suitable for any particular locality depends on the character of the foundation site, the height required, the topography of the reservoir and the funds available. Some cases illustrating the difficulty of finding suitable dam sites are briefly described below.

Some of the rain falling on the surface soaks through the soil into the pervious strata underneath. These water-bearing

rocks may be (1) themselves porous, or (2) may be capable of holding water in joints, fissures and faults. The principal water-yielding porous formations are sands, sandstones and gravels, and of these gravel is by far the best, while sand and sandstone rank next. Clay, shale and slate are the least suitable rocks as sources of water supply. Limestones vary greatly in yield, some being as good as gravel; but others are as unsuitable as clay. Sometimes water dissolves out large underground caves and lakes in limestone formations, and these underground chambers may be large enough for the supply of even large areas. The ground-water under suitable conditions may be tapped by sinking wells.

Climatically Burma is divided into three distinct zones: (1) the deltaic portion, including the Tenasserim division, enjoys an abundant rainfall; (2) the northern hilly portion has also a heavy rainfall throughout the year; but (3), the middle portion or the Dry Zone, has a poor rainfall. Zone (3), as the name signifies, has an average annual rainfall varying from 10 to 40 inches, and the districts of Thayetmyo, Minbu, Pakokku, Sagaing, Shwebo, Lower Chindwin, Mandalay, Kyaukse, Meiktila, Myingyan, Magwe and Yamethin fall within this zone. Although these districts are situated on either bank of the Irrawaddy, the waters of which are perennial, still there are many places in these districts which suffer from want of water especially during the dry season for about three to four months in the year. This entails great hardship on the inhabitants; and in some cases they have even to migrate from one place to another purely for the purpose of obtaining water for themselves and their cattle. Again, the present water-supply of towns like Rangoon is becoming inadequate for the population, which is always on the increase. The water supply problem of the province divides itself mainly into two issues: (1) finding water for the "waterless" tracts of the Dry Zone and (2) obtaining additional supplies of water for some of the growing towns.

THE DRY ZONE.

The prevalent rocks of the Dry Zone are those of the Tertiary system, especially the Irrawaddian, the Peguan and the Eocene

Irrawaddy Series consists mostly of current-bedded, porous sands and sandstones, in many cases of considerable thickness. Among the Eocene formations the Tabyin and Tilin Clays and the Yaw Shales are most unsuited for water storage : any areas situated on these formations are bound to suffer from scarcity of water. The supply of water unfortunately cannot be augmented by sinking tube-wells into them.

The Pegu rocks, where their lithology is fairly well divided between shales and sandstones, are likely to be suitable repositories for underground water; but their upper members are very closely allied to the Irrawaddian sands, which, as a result of their porosity and very incoherent character, have proved barren of water. Most of the waterless tracts of the Dry Zone are situated on these rocks. Moreover, this formation, and sometimes the Pegu Series also, contain disseminated soluble salts, hence even if any water is obtained from them it is generally saline. Even alluvium, where it is derived from the Irrawaddian rocks and is entirely sandy in character, is equally devoid of any store of water ; but where the alluvium is loamy in character and attains a considerable thickness it constitutes very favourable ground for obtaining water. Thus some of the " oases " situated in the Dry Zone are really tracts of alluvium of some considerable thickness. Very good instances of such " oases " are furnished by those of Kalade and Nagathayauk in the Pagau subdivision of the Myingyan district. Similarly, when the Irrawaddian rocks are underlain by those of the Pegu Series at shallow depths, chances of obtaining water by means of tube-wells are not so remote, as the latter acts as an impervious barrier to the downward percolation of underground water. Some specific cases are briefly described below.

Thayetmyo District.—In the Thayetmyo district waterless tracts are confined to the townships of Sinbaingwe, Allanmyo, Minhla, Thayetmyo, Mindon, and Kama. The waterless tracts of the Sinbaingwe township are located on older Irrawaddian rocks whose thickness is not definitely known. This, coupled besides with the fact that their general elevation is over 400 feet above sea-level, renders the chances of obtaining water at shallow depths very remote. In the Allanmyo township the areas which suffer from want of water are situated close to the

junction of the alluvium and the Irrawaddian rocks. By sinking shallow wells into the former, as indicated above, a small supply of water to meet the needs of the local inhabitants may be obtained. In the Minhla township, as also in the other townships named, the scarcity of water is largely due to the absence of tanks in which surface water can be stored. In this township the waterless tracts consist of Eocene, Peguan and Irrawaddian strata. It is useless to seek water in the Eocene and Irrawaddian rocks ; but tube-wells may be sunk into the Peguan rocks with favourable results. The places in the Mindon township which are affected by want of water lie over the formations of the upper Eocene, comprising alternating layers of sandstones and shales which have been affected by dynamic stresses. The detailed examination of these deposits alone at the places where water is required can reveal the possibilities of tapping with ease the underground sources of water. Comparatively little is known of the surface formations of the Kama township, but they seem to consist of Kama clays, and chances of obtaining underground water are remote.

Minbu District.—A number of places in the Sagu, Pwinbyu, and Salin townships of the Minbu district suffer during the dry season. The total area of the waterless tract in the first township is barely 110 square miles. Within this area Irrawaddian rocks and alluvium occur. Some of the places are not only located on Irrawaddian rocks, but are also situated at high elevations. With the exception of Maungmagan, a single large village, seven miles south-south-west of Minbu, where alluvium occurs, the sinking of tube-wells is not advised. The waterless tracts of the Pwinbyu township are composed of the Irrawaddian rocks, and hence there is little hope of obtaining water through tube-wells. In the Salin township there are two tracts covering areas of 100 and 250 square miles respectively, where dearth of water is experienced. In the first area some of the places are drained by the Mon *chaung* ; there are also shallow wells and tanks which become dry during the dry season. Tube-wells may be tried in the alluvium of the Mon *chaung*. In the second area many of the waterless tracts are underlain by Irrawaddian rocks, and hence they are not suitable even for trial tube-wells. In some of these places tanks exist, and the only

means of conserving the available water supply is to increase their capacity. There are other places which are situated on alluvium, and here sinking of shallow wells is advisable.

Pakokku District.—The Pauk, Myaing, Yesagye and Pakokku townships of this district contain waterless tracts ; with the exception, however, of the Shinmadaung area, the predominant surface rocks belong to the Irrawaddian System, and so are unsuited for the accumulation of water at shallow depths. In the Shinmadaung area many of the places lie on Peguan clays and false-bedded sandstones with high dips. In these places the prospects of tube-wells are poor. In the Pakokku township most of the villages are situated either entirely within the belt of Pegu rocks, or, worse still, on the Irrawaddian rocks lying to the west of the former. Some of the other areas are covered by alluvium, and it is suggested that tube-wells may be bored here as near to the Chindwin river as possible.

Lower Chindwin District.—The waterless tracts in the Lower Chindwin district are situated on either the porous Irrawaddian sands or the older alluvium, which is of a semi-porous nature and itself overlies the Irrawaddian Series. The latter contains disseminated soluble salts and also shows very rapid changes in lithology. The sinking of tube-wells cannot therefore be recommended ; but improvements could be effected in tapping the local sources of sweet water and in its storage and distribution. In some areas surface tanks and reservoirs have to be relied on, and much water is lost from these through percolation and evaporation. More care should be exercised in the choice of sites and the water surface exposed should be reduced to a minimum. The wells, for instance in the Budalin township, should be completely lined with impervious material, which should increase the available supply owing to the elimination of loss through percolation. Deepening, in the case of the Irrawaddian rocks, is not to be recommended, as it is liable to cause the water to become saline. The water-table in many places is at a shallow level—and here driving of infiltration galleries, as at Monywa, may be helpful in solving the problem.

Sagaing and Shwebo Districts.—Lake Kadu covers an average area of 40 to 50 square miles. As this lake has no outlet its water is very saline and it is estimated to contain 12·4 per cent.

of sodium chloride. The percolation of this water into the neighbouring areas renders the well-water of these places also saline. In addition to this the surface rocks contain efflorescent salts, hence, when wells are sunk, the water is invariably saline. According to E. J. Bradshaw it is very interesting to note, however, that in this area the presence of a species of *Euphorbia*, *Streblus asper*, locally known as *Okhnebin*, is indicative of the occurrence of good water.

Mandalay District.—The country rocks of the waterless tracts of this district are either alluvium or the crystalline Archaean rocks. The only possibility of obtaining water is by trying wells in the alluvium. These might yield water at comparatively small depths.

Kyaukse District.—Nearly the whole of the Myittha township of this district has been demarcated as a waterless tract, within which the rocks are conglomerates, gritty sandstones and shales of upper Tertiary age, attaining a thickness of nearly 600 feet in some places and dipping rather steeply towards the south-west. Within this area a tube-well was first sunk at Taungdwon village. The well was carried to a depth of nearly 300 feet but proved a failure. On the strength of the data available from this well a suggestion was made to sink another at Thittetkon, about three and a half miles away from the first locality. Success has attended this venture, and now water is obtained at a depth of 75 to 88 feet below the surface from a coarse sandy bed.

Meiktila District.—There are numerous waterless areas in this district. In some places, as at Mahlaing township, the existing sources of supply satisfy the needs of the people in years of good rainfall. In certain other places, as at Aleyan, there is no possibility of obtaining water from tube-wells as the country rocks are all crystalline. There are some other areas which lie on alluvium or Peguan rocks. In these places it has been suggested that tube-wells may be tried in favourable localities—a number of such places have been pointed out by J. Coggin Brown. As a rule tube-well borings are not advised where Irrawaddian rocks occur.

Myingyan District.—In this district the Sinthe, Taungkalin and Miniyin villages of the Taungtha township, about 400 square

miles in the Pagan sub-division, and nearly 200 square miles in the Kyaukpadaung sub-division, have been classified as waterless tracts. At present the villages of the Taungtha township obtain their supply of water from streams and tanks which become dry for nearly three months in the year. In the Pagan sub-division many of the villages are quite close to the important rivers. In the former case the possibilities of tapping the underground water are remote, as the geological conditions are not quite favourable. The same is the case in the other two areas too: but here surface water can be obtained in plenty from the streams issuing from Mount Popa.

Yamethin District.—In this district waterless areas occur in the townships of Yamethin, Pyawbwe and Yanaung. In the Yamethin township the waterless tracts are underlain by loose sandy rocks of the Irrawaddian Series. A trial well sunk to a depth of 52 feet at Kadaing village proved a failure. In East Yamethin, however, shallow wells are reported to contain water throughout the year. Detailed examination of these may give valuable information for elucidating the problem in other areas as well. West Yamethin is hilly, and at present water is supplied by the Indawgyi and Shwe *chaungs* which go dry during periods of small rainfall. In the Pyaubwe township the waterless tracts are generally found in places at an elevation of over 900 feet. In some places the underlying rock is probably crystalline gneiss, and the sinking of tube-wells is out of the question. In the Yanaung township the chief source of water is the Thitson *chaung* which becomes dry during periods of drought. Sand wells are then dug in the stream beds for obtaining drinking water.

Magwe District.—The waterless tract of this district is bounded by the Pyin-ma *chaung*, the Gwegyo-Ngashandaung hills and the Irrawaddy. Most of this area is occupied by Irrawaddian rocks, and hence there are no prospects of obtaining water through tube-wells. Trial borings have proved a failure. In the Paungdaw township, however, large quantities of excellent water are available at reasonable depths. There are instances, of course, where good water is being obtained from the "water-table" of the Irrawaddy. The Nyaunghla tube-well of the Burmah Oil Company furnishes an example of successful boring

through Irrawaddian rocks to below the water-table of the Irrawaddy river. It is 4,250 feet from the Irrawaddy and 175 feet above it. This well struck an almost inexhaustible supply of fresh water between 180 feet and 300 feet below the surface. J. Coggin Brown notes that the Paungdaw wells of the British Burma Petroleum Co. furnish similar additional instances. Both wells are situated close to the river and about two miles west of Twingon, on the Yenangyaung oilfield. In the first well a water-sand was encountered at a depth of between 80 and 132 feet below the surface, but the water was saline and unsuitable both for engineering and domestic purposes. A second water-sand underlain by clay was penetrated between 162 and 186 feet, and the water from this sand is reported to be of excellent quality. Although the well has never been tested it has yielded up to 9,000 gallons per hour since it has been in use. In the second well a good water-sand underlain by a sticky clay occurred between 144 and 272 feet. Although these wells prove that an abundant supply of good water can be obtained from Irrawaddian rocks lying within the " water table " of the Irrawaddy river, yet it would be interesting to ascertain as to how far this " water table " extends to the east and west.

ARTESIAN CONDITIONS IN TAUNGDWINGYI PLAIN.

The villages that suffer from the scarcity of water in the Taungdwingyi township lie either on the alluvium of the Taungdwingyi plain or on the Irrawaddian rocks, which surround this broad expanse. Taungdwingyi itself is situated on the alluvium, but quite close to the Irrawaddian band which intervenes between it and the Pegu. It possesses three tube-wells of six inches diameter sunk in 1917. Two draw their supplies from a gravel band between 79 and 89 feet from the surface, and the third from a similar layer at 102 feet to 120 feet. The yield of the first two wells was 3,000 gallons per hour, and 1,750 gallons per hour in the case of the third. They have probably penetrated the alluvium and entered the underlying Irrawaddian rocks. The first two wells overflowed at a rate of 2,000, and the third at 88 gallons per hour. Water under true artesian conditions has been proved to exist underneath the Taungdwingyi

plain. It is perhaps collected on the high ground of the Pegu Yoma to the east, and, being unable to enter the comparatively impervious Pegu rocks, flows down along their junction with the Irrawaddian rocks and accumulates in them beneath the alluvium of the plain.

WUNDWIN TANK, MEIKTILA DISTRICT.

The Wundwin project briefly described below furnishes an instance of a dam site having to be condemned owing to the rocks being sandy and impregnated with efflorescent salts, principally sodium carbonate. The examination of this project for irrigation works was necessitated as both the bund and the weir of the old Wundwin Se, situated half a mile west of Wundwin, broke during the floods of 1926. The dam site of the proposed Wundwin tank was at Leinbin, one and a half miles west of Wundwin village, Meiktila district (96° 3′ 22″, 21° 5′ 16″). A number of trial pits and borings were sunk along the dam line, and hard brown clay and compact sand rock were met at reasonable depth in some of the borings. In other cases, however, on either bank, sand, sand-rock, clay and *kankar* impregnated with efflorescent salts were encountered. At the site of the proposed works the Wundwin *chaung* has cut through a low sandy ridge of upper Pegu or Irrawaddian beds. It is composed of hard compact sand, sand-rock, gravel and beds of clay; in places both the sand and clay are highly impregnated with efflorescent salts. Below the water-table, where the ground is damp at the foot of the ridge, the sand and clay become very sticky owing to the presence of salts. The right bank is chiefly sandy, and the clay and sandy beds on the left bank are so highly impregnated that the ridge, if saturated, would almost certainly be breached by any water impounded behind it. The greater part of the floor of the proposed tank is composed of alluvium, which is thin and sandy in places, especially near the dam line.

THE THITSON RESERVOIR PROJECT No. 1, YAMETHIN DISTRICT.

This dam site had to be abandoned on account of the permeable nature of the site and also of the impounding area. The

geological structure also was not favourable. The Irrigation Department of the Government of Burma proposed to construct an earthen dam across the Thitson river in the Yamethin district, and thereby form a reservoir with a full capacity of 13,000 acre-feet and an estimated water-spread of 1250 acres. Geological advice was requested as to whether the area, included within the proposed reservoir, was suitable for the purpose and whether the site chosen for the construction of an earthen dam, 1,800 feet long, with a freeboard of 3·62 feet above high-water level, and a maximum height of nearly 70 feet, was also suitable for its purpose. The investigation was undertaken by J. Coggin Brown. The greater part of the catchment area is built of the Pegu Series. In the east, however, these give place to the Irrawaddians. The dam site and the eastern end of the impounding area lie on Irrawaddian rocks, which crop out, generally as soft sandstones or sand-rock, false-bedded, possessing little cohesion and poorly consolidated. Such materials are obviously porous, become quickly soaked with water, and owing to their loose friable character may then suffer disintegration. On account of the pervious nature of the strata there would be a leakage from a reservoir constructed on them. Some clay or clayey layers met with in the trial pits are merely lenticles of irregular shape intercalated amongst the permeable sandstones. In the absence of any such continuous impermeable layer it is doubtful whether a water-tight dam could be constructed in this situation. Another unfavourable structural feature, as distinct from a lithological one, is the change in the dip of the sandstones from their original upstream direction to a dip nearly downstream near the proposed site. This outward dip from the reservoir would augment the tendency towards leakage caused by the porosity of the beds themselves.

A new site upstream called the "Thitson River Reservoir Project No. 2" was therefore selected, and three dam lines had been tested in the vicinity of Magigon village. The first of these had been rejected chiefly on account of the abundant presence of "*kyatti*" in alkaline earth in the trial pits. Again, the rocks on which it was proposed to build the dam were the higher members of the Pegus and were not dissimilar from the Irrawaddian rocks. The boundary between the Pegus and the

Irrawaddians lay just below the dam line. Again on geological grounds A. L. Coulson, who examined the site, condemned it on account of the porous nature of the strata and also on account of the general dip being downstream.

UNDERGROUND WATER SUPPLY OF RANGOON.

The population of Rangoon, the capital of the province, is increasing very rapidly, and to find an adequate supply of water to cope with the needs is an acute problem of the day. R. D. Oldham published a very useful note on the alluvial deposits and subterranean water supply of Rangoon in 1893.[1] He discussed briefly both aspects of the problem, viz., the quality and quantity of the available supply. It has been observed that the wells which have not been contaminated by salt water have yielded excellent fresh water. The same author noted that water-bearing gravels were almost continuous underground, and the wells sunk farther to the north, that is farther away from the outlet to the sea and more within the influence of the principal catchment area, would be certain to yield fresh water. The quantity procurable from the wells is an uncertain factor. The yield of the several wells varies very much—one with a very poor yield being situated within a few hundred feet of one with a very good yield. Oldham concluded that the gravels are subject to local and capricious variations of permeability. The wells sunk so far are not artesian, the natural water-level in them being some feet from the surface.

The rocks of Rangoon and the neighbourhood have been described as follows :

Upper Delta Alluvium	- sub-Recent and Recent	Quaternary.
Lower Delta Alluvium	- Pleistocene	
Irrawaddian Series	- Pontian-Pliocene	Tertiary.
Pegu Series - -	- Oligo-Miocene	

For the details of the geology the interested reader may refer to P. Leicester's recent report.[2] The main point to be

[1] *Rec. Geol. Surv. Ind.* vol. xxvi, 1893, pp. 64-70.

[2] *The Geology and Underground Water of Rangoon*, Government Printing, Rangoon, 1932, pp. 1-78.

noted here, however, is that in the Lower Delta Alluvium four bands of gravels, A, B, C and D, occur at depths from which water is obtained by tube-wells. In the Upper Alluvium there is also a gravel bed, E. These gravels are not nearly so regular as those of the lower gravels though they are composed of much the same material.

In his report P. Leicester has tabulated the geology of the tube-wells that have been sunk in and around Rangoon, and has also divided the city into twelve zones each indicating water of different origin and quality, and in which the possibility of extension of the supply varies.

Block A.—Bounded by the Hlaing river on the west, the Rangoon to Prome railway on the east, and the Hanthawaddy Road to the south.

Block B.—Bounded by the Rangoon river on the west, Station Road on the east, Hanthawaddy Road on the north, and Bulloch Street on the south.

Block C.—Bounded by the Rangoon river on the west and south, Keighley Street and Strand Road on the east, and Bulloch Street on the north.

Block D.—Bounded by Bulloch Street, Kemmendine Road, Commissioner Road, Keighley Street, and Strand Road.

Block E.—Open on the north and bounded by the Rangoon to Prome railway, Station Road and Lower Kemmendine Road, Commissioner Road and Keighley Street on the west, by Dalhousie Street on the south, and Godwin Road, Halpin Road and Prome Road on the east.

Block F.—Bounded by the Rangoon river, Strand Road and Merchant Street on the south, Judah Ezekiel Street on the east, Montgomery Street and Commissioner Road on the north, Godwin Road, Dalhousie Street and Keighley Street on the west.

Block G.—Bounded on the north by Strand Road and Merchant Street, on the east by Judah Ezekiel Street, and on the south by the Rangoon river.

Block H.—Bounded on the north by the Victoria Lakes and Prome Road, on the west by Prome Road, on the south by Boundary Road, and on the east by Windermere Road and Lowis Road.

Block I.—The northern boundary runs from Malagon Railway Station due east to the Pazundaung Creek in Upper Pazundaung; the southern boundary is Strand Street, Lower Pazundaung, the eastern boundary the Pazundaung Creek, and the western boundary the main Rangoon to Mandalay railway line.

Block J.—Embraces eastern Kokine, Kanbe, Tamwe and part of Upper Pazundaung.

Block K.—Covers the eastern part of Golden Valley, the area

around Campbell Road, Shwegondaung Road, Tamwe Road and Park Road, north of the Royal Lakes, the Shwe Dagon Pagoda hill and the area between the railway station and the Royal Lakes.

Block L.—Represents Mokey Point, Dannidaw, Botataung and part of Lower Pazundaung.

Favourable Blocks.—Blocks A, B, C, D, E, F, H and I yield, on the whole, a plentiful supply of fresh water. However, the following exceptions are worthy of note. Near the boundary between Blocks A and B, and the south-east corner of Block H and in Block F there appears to be much hydrated oxide of iron in the water. On standing for some time or on boiling ferric oxide is precipitated, imparting a red colour to the water. This iron content is believed to be derived from the ferruginous sands embedded in the gravel. The percentage in Block E is higher, while in Block F it is higher still. In Block G the percentage of iron is so high that most wells sunk there have been condemned on that account. It perhaps resembles a stagnant bay, away from the active areas to the west. Whenever the water is in active circulation, even near the Irrawaddian boundary, the ferruginous content is not so marked.

Along the river in Block C, when large quantities of water are being extracted, brackish water from the river has gained access to the gravels and sands, with the result that some wells at the northern and southern extremities have had to be abandoned. So far the salt water has penetrated inland to a distance of about 300 feet at the northern end, and about 400 feet at one place near the southern extremity of the block.

In some cases wells have proved failures, and it is believed that these are more probably due to faulty sinking of the well than to any lack of underground water. It is suggested that precautions to avoid such failures in future would seem to be:

(1) the proper locating of the water-bearing gravel, which could be done by the slowing down of the drilling as a known gravel horizon is approached; (2) moderate pumping; and (3) the use of suitably fine strainers. The last two precautions would prevent choking of the well by avoiding the drawing up of fine sand through the gravel.

Unfavourable Areas.—It has been mentioned above that the water obtained in Block G is very rich in iron. Here not many

wells have been bored, but those that have been put down have not been very successful. Block K is almost a barren area, as numerous wells which traverse the Irrawaddian Series have failed to yield any water. On account of the easterly dip of the beds the water flows eastwards away from this area. However, some water may be obtained in the neighbourhood of the Royal Lakes as a certain amount of water percolates through from them. Similarly, the prospects of obtaining any permanent supplies of fresh water from Block L are very remote.

In Dalla, Twangte and Kanoungto, large quantities of brackish water may be obtained from the gravel; but it is reasonably assumed that there is practically no chance of obtaining fresh water from tube-wells in these areas.

Insein.—In Insein, according to Leicester, the water-bearing gravels are met with between 80 and 170 feet below ground level and away from the river; the supply of fresh water would seem to be assured for some years to come. In Insein the boundary of the Irrawaddian rocks runs to the east of the Rangoon Road as far as the Yegu Lane, but here it crosses the road and traverses the Golf Club ground. Running north-by-west across Station Road just west of the Veterinary College, and across East Road just east of its junction with Civil Station Road, it continues northwards through the high ground of the Civil Station to the east of the Insein Technical Institute. All wells should be located to the west of this line, though small quantities of water are obtained from the Irrawaddians in places.

Mingalodon.—At Mingalodon, on the western side of the ridge, large quantities of water are obtained for the cantonment supply. The successful wells are located on a tongue of alluvium which forms a bay in the ridge of the Irrawaddian Series. The gravel bed is here a coarse shingle, and the test borings showed a thickness of 50 feet of hard clay underneath the shingle which slopes gently westwards and thins out in that direction. It is concluded that this small bay should not be taxed too far; but there should be water available elsewhere at the foot of the ridge sufficiently far to the west to avoid the Irrawaddian strata.

North of Rangoon.—P. Leicester states that to the north of Rangoon water should be available from the Lower Alluvium on the west of the ridge, as at Kamayut, Insein, and Mingalodon. Water is obtained as far north as Wanetchaung and even farther north in the Hmawbi area. On the east of the ridge, however, prospects are not so bright. It seems very probable that the sinking of wells in Irrawaddian strata on the west and centre of the ridge would, in most cases, result in failure.

The Initial Store of Subterranean Water.—The area from which water is obtained lies as a structurally distinct area to the west of the ridge and the areas to the east are insignificant in comparison. It is believed that on the west of the Rangoon ridge the origin of the underground water is not from the north by underflow parallel to the river, but from the porous catchment area of Lower Delta Alluvium flanking the main ridge of Irrawaddian rocks. Leicester has calculated that the total volume of water held in this area should be 7,560,000,000 cubic feet, or 46,912,000,000 gallons. He has calculated the life of this basin as 49 years, if 1,060,000,000 gallons of water be extracted annually. The amount of annual addition to the store of water has been computed to be about 1,635,000,000 gallons per annum, or 4,480,000 gallons *per diem*, while the amount of water extracted daily has been estimated to vary from 3,500,000 to 5,000,000 gallons *per diem*.

The Menace of the Irregular Distribution of Wells.—The southern half of the area produces most of the water, and Blocks C and F most of all. Blocks C, D, F and G, and half of Block E, represent a quantity of 773,000,000 gallons of water extracted as against 817,000,000 gallons contributed per annum by half the catchment area. It leaves a remarkably small balance, which provides no allowance for error in the estimates. Leicester has drawn the following conclusions :

(1) If the present rate of pumping is continued, before long the eastern portion of Block F, together with Block G, will probably become brackish.

(2) It is possible that Block C and the remainder of Block F will eventually become brackish, and will almost certainly become so if there is any large increase in the quantity of water extracted from these areas.

(3) The prospects of obtaining adequate supplies of fresh water in Kamayut and farther north towards Insein are favourable.

It has been suggested that:

(*a*) wells should not be sunk within 500 feet, and preferably not within 1,000 feet, of the river;

(*b*) in Blocks A, B, C and D well owners should be encouraged to pump during low tide only, and pumping should be restricted to three hours before and after low tide;

(*c*) no wells should be sunk in Blocks C, F and G unless they replace wells which have been closed down. Similarly, the number of additional wells sunk in Blocks B, D and the southern portion of E should be very strictly limited;

(*d*) any increase in supply must be obtained from farther north, and even there only reasonable quantities of water should be extracted.

Rangoon Water Supply : Hlawgaw Low Level Lake Scheme.

Closely interconnected with the question of the underground water of Rangoon is that of the surface supply, which satisfies by far the greater part of the city's needs. A new reservoir site was selected by the Rangoon Corporation for consideration from the numerous schemes for the extension of the existing inadequate supplies. The impounding area lies on the rice fields to the east of the low shelving ridge between miles "14" and "21" of the Rangoon-Prome Road (17° 0′, 96° 40′) and it is proposed to construct a shallow reservoir, 15 feet deep, with the take-off about 9 feet below high-water level, by means of low earthen bunds. By far the greater part of the impounding area of the proposed reservoir rests upon the homogeneous clay of the Upper Delta Alluvium, which should form a practically impervious and therefore ideal floor for a reservoir of this kind. It was suggested by P. Leicester, who conducted the examination, that at the point where the "*bunds*" cross the streams the silt bordering the latter should be removed and the impervious core of the dam sunk well below the old stream bed into the ridge and below any laterite met in it. A certain amount of river training may be necessary, and in exceptional circumstances certain parts of the outside of the "bunds" might

have to be protected by pitching and rubble aprons. Leicester concluded that the area should be suitable for the construction of a watertight reservoir bounded by earthen " bunds."

UNDERGROUND WATER SUPPLY OF BASSEIN.

Similarly, in the investigation of the underground water at Bassein, P. Leicester stated that two gravel beds exist in the Lower Delta Alluvium dipping towards the river. The upper gravel is, on the whole, not so coarse under the higher ground as the lower gravel, which has a thickness there of about five feet. The top of this upper gravel bed is at a reduced level of − 117 feet (G.T.S. datum at Myetto). The lower gravel bed appears to be coarser, thicker, and rather less regular than the upper gravel, and the top of the former is at the reduced level of 212 feet at Myetto. A study of analyses shows that wells sunk into the lower gravel yield brackish water (36 to 68 parts of chlorine per 100,000) with high total solids; while wells sunk into the upper gravel and situated not far from the river, yield fresh water (2 to 11 parts of chlorine per 100,000) and low total solids. According to Leicester the brackish water represents a vast store of occluded sea water lying beneath the delta. Further pumping might draw in more brackish water, as the superficial covering of the impermeable Upper Alluvium prevents any large quantities of water soaking downwards and diluting the salt; while the more superficial fresh water of the zone bordering the river must be derived from the river itself, the water of which contains less than 1 part per 100,000 of chlorine and remarkably low total solids. It was therefore advocated that to improve the water supply of Bassein tube-wells should be drilled near the river bank into the upper gravel.

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CHAPTER XVI

ROADSTONES AND BUILDING MATERIALS.

A. ROADSTONES.

WITH the invention of the internal combustion engine it is becoming essential for the development of a rice country like Burma to possess a good system of roads, linking her main river towns with the railway termini and seaports. Many miles of the old tracks laid down during the days of the Burmese kings have now been reconstructed, and, in addition, some new highways have been constructed. In Europe and in America the modern practice of the highway engineers, in constructing trunk roads, is to lay down a Portland cement concrete foundation, 6 to 15 inches in thickness, with a wearing surface of rich concrete, of asphalt or of tarred macadam. In Burma, however, as Portland cement, bitumen and tar are not available so cheaply as in Europe and America, the roads connecting the various towns are mainly of water-bound macadam construction.

The qualities of a good roadstone are: good crushing strength, high attrition and resistance to abrasion, good cementation value, low porosity, and high specific gravity. A thorough series of tests on various roadstones was carried out by Lovegrove,[1] and the comparative values arrived at by him are as follows. His scale of quality ranges from 0 to 20:

Porphyry	varies from	10–20
Trap	,,	16–20
Basalt	,,	10–19
Quartzite	,,	11–19
Flint	,,	8–19

[1] *Tests on Roadstones, Results and Samples in Geological Museum, London.*

Quartz varies from	- -	10–18
Serpentine ,,	- -	12–18
Diorite ,,	- -	13–17
Limestone ,,	- -	5–17
Gneiss ,,	- -	5–17
Millstone grit ,,	- -	6–16
Mica-schist ,,	- -	6–13

Basalts and dolerites, especially the former, are the best rocks for water-bound road construction. If these are not available other igneous rocks such as granites and syenites may be substituted. Sedimentary and metamorphic rocks are not so good for water-bound road work, but have to be employed when more useful material fails.

Not very long ago (really before the advent of the steamships) the sailing vessels visiting the port of Rangoon to take away rice, teak, and other materials of export, used to bring in stone-ballast as " sinking " cargo from Bombay ; and in some cases as far as from ports in Brazil and from Mauritius. This stone-ballast found a ready market in Rangoon, no local roadstone being available in the Delta, which is almost entirely composed of alluvium. As late as 1873 Theobald [1] stated that " excellent road material in the shape of ship's ballast is procurable in Rangoon " ; but with the advent of steamships, with water ballast, the supply of foreign roadstone to Rangoon decreased ; and this led to the necessity of exploiting local resources.

Thaton District.

When the cost of foreign stone proved prohibitive it was the Thaton district which first received attention, and in which quarries were opened up in Burma. About 1905 the assistance of J. Coggin Brown was invoked to report on the various outcrops of stone that were known to exist along the line of the Pegu-Martaban Railway, then under construction. He reported that the outcrops in the Mokpalin area were favourable, and that the stone was of a very good quality for road-making purposes, " a two-inch cube not giving way under a pressure of 40,000 lbs., and another specimen only breaking when the

[1] *Mem. Geol. Surv. Ind.*, vol. x. 1873, p. 163.

pressure reached 9½ tons per square inch." Other areas were explored, and suitable stone was found at Zingyaik, Kyaikto, Taungzun, Donwun, Theinzeik, and Martaban.

Later on P. N. Datta of the Geological Survey of India was deputed to report on the various possible quarry sites in the Thaton district. The outcrops at Kyaikto, Theinzeik and Donwun were condemned as unsuitable, but those near Mokpalin (including Tanaw), Taungzon and Zingyaik were recommended for further investigation. Later on a committee of experts was appointed and visited each of the outcrops near Mokpalin, Taungzon and Zingyaik. They recommended that these areas be reserved pending further investigation.

The quarry at Martaban was then considered as too inaccessible, being 121 miles from the main Rangoon-Mandalay railway line and 168 miles from Rangoon. A very suitable stone is found there in the hill on which the P.W.D. bungalow is situated, and the railway company took out a large quantity of excellent stone ballast.

A brief summary of the report of P. N. Datta, who examined the following localities at the commencement of the field-season 1908-09, is given below. It indicates the historical development of the quarries in the Thaton district :

I. Tanaw area, near Mokpalin (17° 26′, 96° 56′).
II. Toungale, 3 miles N. by E. of Kyaikto (17° 19′, 97° 3′).
III. Taungzun (17° 12′ 30″, 97° 10′ 30″) which includes :
   (i) The hill range just at the foot of which Taungzum railway station stands.
   (ii) Kyibin (17° 14′, 97° 10′).
   (iii) Koko (17° 14′, 97° 11′ 30″).
   (iv) Sinin (17° 14′, 97° 11′).
IV. Donwun (17° 8′, 97° 19′).
V. Theinzeik, or Kyaik Kaw (17° 3′, 97° 21′), to which was added, at the request of the Executive Engineer, Pegu Division, another locality, viz.,
VI. Zingyaik (16° 42′, 97° 28′).

I. **Tanaw Area.**—The village of Tanaw stands on the left bank of the Sittang river, 6 miles north of Sittang (17° 27′,

29° 55′ 30″), or 7 miles north of Mokpalin railway station on the Pegu-Moulmein railway line.

The present quarries, from which stone has been raised for some time by private firms, are situated 2 miles due east of Tanaw, close to the bed of the Tanaw, a small stream flowing between hills which rise to a height of 100–150 ft. above river level.

II. **Toungale.**—This is a small hill, rather oval in outline, 3 miles north by east of Kyaikto (17° 18′, 97° 3′), with a height of 300 ft. above the sea-level. It is composed of quartz-schist, in thickish beds, dipping at a high angle.

III. **Taungzun Area.**—This includes :

- (i) The big hill range at the foot of which Taungzun railway station stands.
- (ii) The ground by Kyibin.
- (iii) The ground by Koko.
- (iv) The ground by Sinin.

(i) *The hill range by Taungzun railway station* (17° 12′ 30″, 97° 10′ 30″).—This range, the south-eastern extremity of which is by the above-mentioned railway station, extends for five miles north-westwards, with a width varying from a half to two miles, and is formed of a coarse to medium-grained granite consisting of quartz, felspar, with some mica. While the height of the range is 1128 ft. above the sea-level at its south-eastern extremity, it is 1187 ft. high at Kalatha Hill, diminishing gradually in elevation northwards.

The Burma Railways Co. has opened quarries for their ballast-stone at the foot of the granite range by the Taungzun railway station. Associated with the rock in these quarries iron pyrites and molybdenite occur in isolated tiny pockets.

(ii) *The ground by Kyibin.*—A quarter of a mile south-east of Kyibin village is the northern extremity of an oval hill which extends in a north-west–south-east direction, with a length of three-quarters of a mile and a width of about half a mile. The height of the hill at its southern extremity is about 80 ft. above its base, which may be taken as on a level with the railway line. According to P. N. Datta the rock exposed at its northern extremity is a fine-grained quartz-pyroxene-gneiss,

while exposures at its southern end show it to be hornblende-gneiss. There is little doubt that the whole of this hill is formed of gneiss.

(iii) *Koko.*—Just north-west of Koko village is a rounded hill, three-eighths of a mile long and a little over a quarter of a mile broad, rising to a height of 140 ft. above its base. It is formed of hornblendic gneiss. P. N. Datta suggested that quarrying might commence at Koko and be continued south-westwards towards Sinin.

(iv) *Sinin.*—A quarter of a mile east of Sinin is an oval hill stretching in a north-west–south-east direction, with a length of half a mile and breadth varying from one-quarter to three-eighths of a mile, and rising to a height of 90 ft. above the level ground at its base. The rock is a gneiss similar to that of Koko and Kyibin. The hill on which the pagoda stands, half a mile almost due north of Taungzun railway station, is formed of a soft granite.

IV. **Don Wun.**—About half a mile east of Don Wun railway station a low range of hills, extending north-by-west–south-by-east, consists of sedimentary rocks—shales and quartzites. P. N. Datta was of the opinion that they would not furnish any good roadstones, especially as better igneous and metamorphic rocks occur in the neighbourhood.

V. **Theinzeik (Kyaik Kaw).**—Two kinds of rocks are exposed here, namely :

(1) Crystalline—gneiss.
(2) Sedimentary—shales and sandstones.

The gneiss is a coarse-grained foliated rock, which forms the hillock with the pagoda by the police lines at Theinzeik.

Shales and quartzitic sandstones form the range of hills just east of Theinzeik, and this range is a continuation of that met with at Donwun.

VI. **Zingyaik.**—Zingyaik stands at the western foot of the large hill-mass of which Kalamataung is the highest point (3025 feet), the hills seeming to rise abruptly from the alluvium. The hill-face fronting the sea (the Gulf of Martaban) is rather steep. The lower parts of the slopes, falling to a height of 1000 feet or more by Zingyaik, are formed of gneiss, the rest of

the hill-mass (including, of course, the summit range), on which the Zingyaik pagoda and the Kalamataung hill station are situated, is of granite.

The gneiss is well exposed by Zingyaik and all along the western foot of the hills. In fact, the lower slopes by Zingyaik really form a continuation of the gneissic range which, beginning near Aungsaing railway station, runs south-east by Yinyein, Zingyaik and Paung, terminating about a mile south-east of the last-mentioned locality.

The gneiss, composed of quartz and felspar with some biotite, is well foliated. It is coarse-grained on the whole, but occasionally becomes finer-grained and more compact.

The granite forms the rest of the Kalamataung hill-mass, *i.e.* extending from a point 1 mile south of Kadaik (16° 46′, 97° 28′) southwards as far as Gangaw (16° 36′, 97° 33′) with a width varying from about a mile, as near Kadaik, to about 4 miles southwards, as east of Paung (16° 37′, 97° 30′) or west of Ontabin (16° 39′, 97° 35′), and is generally very coarse-grained. Its extreme coarseness and porphyritic character are especially well seen by Kywegaon (16° 36′, 97° 31′), Gangaw (16° 36′, 97° 33′) and neighbourhood.

Other important occurrences of roadstones in the district are as follows :

(1) The extensive hill-mass, a few miles to the north-east of Kyaikto (17° 18′, 97° 5′), on which the Kyaikto Hill station (17° 29′, 97° 8′ 30″), with its famous pagoda and pilgrim resort, is built, and forms the highest point (3617 feet) in the district, is formed of granite which is generally coarse-grained.

(2) The hill-ranges on the right bank of the Bilin river, *i.e.* extending from near Natkyi (17° 27′ 30″, 97° 18′) to Bilin (17° 13′ 30″, 97° 17′), are also formed of coarse-grained granite.

(3) The range 3 miles due east of Bilin, and running with a breadth of 1 to 2 miles in a north-west–south-east direction for several miles, is formed of shales and sandstones. Parallel to this range in its southern parts are two others, viz. :

(4) Don Wun–Theinzeik Range, (5) Thaton Range—soft shales with sandstones.

(6) Martaban Range. This is a range of hills that commences at the Martaban railway station and stretches in a

north-west direction, terminating in the neighbourhood of Kyauksait (16° 38′, 97° 36′ 30″). Shales and sandstones, which are well exposed by Martaban railway station, make up the range.

All the above localities lie within easy reach and access of the Pegu-Moulmein railway.

At present all the stone used in Rangoon and the neighbourhood comes from the Mokpalin quarries.

Amherst District.

In the Amherst district, limestone, quartzites and laterite are largely used for metalling the roads. Limestone hills occur close to the Moulmein-Amherst road, but the rock suffers from the disadvantage of easily going into solution under heavy rains and sometimes transverse hollows across the road, marking the water channels during the rains, are formed. Important granite quarries exist on the Kalagauk Island.

Tavoy District.

All the roadstones used in the Tavoy district come from the local granite ranges, though in some localities harder members of the Mergui Series are also quarried for the same purpose when granite is not available in the neighbourhood. The following remarks are based on the Reports of the Public Works Department, Local Resources of the Tavoy District, 1925. There are quarries in the granite at mile 6 on the Kamyakin-Zalut road and at mile 5 on the Tavoy-Talaingya road along the coastal ranges, and again at mile 14 on the Pagaye-Hermingyi road, and at miles 19 and 21 on the Tavoy-Myitta road on the west of the central range. Another quarry at mile 26 on the Tavoy-Myitta road is also in granite and is situated on the east of the central range. These granite quarries, worked recently in the district, produce a very good hard stone. A decomposed very porphyritic granite is obtained on the Kamyawkin-Zalut road and is used for surfacing in preference to both laterite boulders and gravel. Such stone, however, would not prove suitable as road metal, as it is too soft and a large percentage of sand would be derived from breaking or crushing.

All other quarries in the district produce greyish-blue schist which varies in quality and occurs in all grades, from a weathered phyllite to a crystalline rock with veins of quartz. These schistose rock quarries are situated at miles 2, 5, 7, 10 and 13 along the Tavoy-Mindat-Pe road, at miles 5 and 12 along the Tavoy-Myitta road, and at miles 9 and 15 along the Tavoy-Talaingya road. All quarries in the district are Government-owned with the exception of three at miles 2, 7 and 13 on the Tavoy-Mindat-Pe road, which are privately leased. Most of the Government-owned quarries are provided with vertical boilers and crushers and with magazines for the storage of explosives. Trolley waggons are used to transport the boulders along rails from the quarry face to the crushers, where they are converted into road-metal of gauge from 1½ in. to 2 in. The finer grades, resulting in "crusher fines" or "choppings," are used effectively for purposes of binding or topping. All quarries are reached by means of well laid out approach roads, surfaced with road-metal or river-shingle. The machinery, however, installed at the time of the wolfram boom at most of the quarries, is little used nowadays, because of the extra cost of machine-broken over hand-broken metal.

It will, therefore, be seen.that the existing metalled roads of the district are well served with quarries. The future needs can be equally well met, as stone is available in abundance along all roads.

No quarry exists near Tavoy and the road-metal has to be carted either 6 miles from Zaha off the Tavoy-Talainya road, or 6 miles from Thabya off the Tavoy-Myitta road, or 4 miles from Pauktaing off the Tavoy-Mindat-Pe road. The granite obtained from Zaha provides much the best metal. The schist at Pauktaing is a softer stone, while that at Thabya is of an intermediate quality.

Mergui Division.

The district of Mergui, like that of Tavoy, is mainly built of granite and the Mergui Series with some laterite. The local resources of road-metal are more abundant than the needs of the district, which consists chiefly of islands; hence long main roads are only few in number. Two important quarries, viz.,

the Patit and the Pataw, exist on the islands almost opposite Mergui town and approximately half a mile distant. Hard conglomerate, sandstones and grits are being quarried on these islands and are used in the harbour construction work along the margin of the town.

The Kywegu quarry is situated at a distance of 7 miles 6 furlongs north-east of Mergui on the Mergui-Kyaukpya-Tavoy road, and the quarry road turns south at this furlong post for a mile.

Myitkyina District.

The roads in the town of Myitkyina are metalled with :

1. Boulders, largely of igneous origin, collected from the banks and low cliffs of the Irrawaddy. Being water-worn, even on breaking some of the surfaces still remain rounded and thus they do not interlock and cement well. After heavy rains the road becomes almost entirely unconsolidated.

2. Serpentine from the neighbouring hills. This binds very well ; but it has the serious disadvantage of crumbling easily under heavy traffic. However, it serves its purpose well on some of the less important roads of the town.

3. Laterite, quarried between Pidaing and Myitkyina. This is mainly used for metalling private roads or where the traffic is not heavy.

Serpentine, crystalline-schists and quartz (from the veins in the schists) are used as road-metal in Mogaung town.

Among the roadstones likely to be used in the Mogaung sub-division of the Myitkyina district the crystalline-schists of the Sawching *hka*, of Namti, and of the Wolai *hka* are the most suitable ; after these come the serpentines of Pidaung, of the 16th mile on the Hopin-Nampadaung road and the 22nd mile on the same road. The softer Tertiary sandstones should be employed when the harder rocks are not available.[1]

Katha District.

In the Wuntho sub-division of the Katha district the igneous rocks, especially the volcanic breccia of Shinmadaung hill, is used extensively as a road-metal.

[1] *Rec. Geol. Surv. Ind.*, vol. lxiii., 1930, p. 28.

Shwebo District.

In the Shwebo district the basalt from the hill opposite and from Kyaukmyaung, also the Pegu sandstones, are used as roadstones. *Kankar* is also abundant in places, especially close to the Irrawaddian alluvium boundary.

A vesicular basalt occurs east of the Irrawaddy river and is used locally for metalling roads. The rock is quite fresh and unweathered, and, as the traffic on the roads is not great, it is found to suit the local conditions very well and is much in demand. It has the additional advantage of easy access. The harder boulders are picked up and taken over the river in boats to Kyaukmyaung for disposal.

Along the Kin-U-Kabwet road and the Shwebo-Kyaukmyaung road hard varieties of sandstones are picked up from the surface and broken into ballast.

Kankar occurs in large quantities on the surface of the Irrawaddian rocks of the Mu valley in the Shwebo district, usually as small nodules, but occasionally reaching diameters of 2 or 3 inches, as, for example, near Ywamandaung. It could be collected and used for lime and mortar manufacture if desired. It is also particularly abundant near the boundary of the Irrawaddian Series with the alluvium, and at many localities of this type it is quarried for ballast and for use on " semi-pucca " roads, as, for example, at Thanbo and Magyidon. It is also extensively quarried a little west of Halin and near Thayaing.

Meiktila District.

V. P. Sondhi [1] examined the site of a quarry for road-metal at Shansikangon, half a mile north of 14-mile–3-furlong post on the Thazi-Taunggyi road. The rocks of the site consist of granite-gneiss, biotite-schist, and quartz-porphyry. The last-named is best for road-making purposes.

Yamethin District.

E. J. Bradshaw [2] investigated a site for a quarry at Shwedwin (19° 52′ 48″, 96° 15′), about 3 miles east of Kyidaunggan station on the Rangoon-Mandalay main line, for supplying

[1] *Rec. Geol. Surv. Ind.*, vol. lxiii., 1929, p. 34. [2] *Ibid.* p. 34.

road-metal for about 100 miles of the new Rangoon-Mandalay trunk road. It contains two dominant rock types, whose chief macroscopic difference is one of texture, both being light-grey biotite-granites. He recommended that the quarry should be located on an outcrop of the finer variety of the rock, of which there is an enormous and practically inexhaustible supply, and which possesses the additional advantage of being actually in sight and free from overburden. Although granite is not an ideal road-metal, since both its "toughness" and "cementing value" are usually low, it nevertheless ranks fairly high. In the present case the fine-grained variety is sufficiently tough to be satisfactory, and is probably more suitable for the purpose than any other rock to be found in the neighbourhood.

Lower Chindwin District.

A number of hills built of volcanic igneous rocks, *e.g.* basalt, occur in the Lower Chindwin district. These are quarried in places to be used as road-metal. Similarly, the Pegu sandstones are used for the same purpose.

Basalt, which forms a dome-shaped hill half a mile in diameter, with a height of over 100 feet, is quarried for use as road-metal at Wetpyu Taung. The rock constitutes one of the best road-metals of the district, but has the disadvantage of having to be transported by bullock carts for about 20 miles before it can be put to any use.

Similarly large quantities of basalt are quarried from the Shahyindaung hill, about 3 miles north of Alon. At Okpotaung, however, the rock is vesicular and inferior in quality to that of Shahyindaung.

At Kandaw quartz-gravel occurs in large local concentrations near the surface of the alluvium. It is used as ballast for the Ye-U branch of the Burma Railways. The basalt employed for road-metal between Budalin and Ye-U is obtained from the Inde crater.

Shinmadaung Area, Pokokku District.

B. B. Gupta was asked to investigate and report on the existence of road-metal near the Shinmadaung area. His

search was confined to the vicinity of the villages of Kabauk, Yagigon, Gwebinya, Taunggya, Thayetpingau, Kyanzein and Tachanbe, particular attention being devoted to the area included within the circle of these villages.

In this area sedimentary, igneous and metamorphic rocks are all seen to occur. The sedimentaries belong to the Pegu Series, and the igneous rocks include volcanic agglomerate and breccia, volcanic ash, altered lava and olivine-basalt. The sandstones are too soft to be used as road-metal. The volcanic and metamorphic rocks are more suitable, but the first three of the volcanic types are hardly suitable, as either the quantity of the rock available is too small or the rock is too soft.

The hill north of Thayetpingau (887), according to K. A. K. Hallowes, consists of olivine-basalt. The rocks forming this hill are very tough, and there is a large amount of material available for quarrying. The rocks are more compact in the south-western part of the hill, but are more or less vesicular in the remaining portion. B. B. Gupta therefore recommended that the basalt, especially from the south-west portion of the hill, be quarried for road-metal. Though there is some difference in compactness of texture of the rock in different parts of the hill, yet both the vesicular and the more compact varieties will make excellent road-metal. Sufficient material is available on the slopes of the hill to supply the need without quarrying for some years to come. Further, the locality is conveniently situated in relation to riverside stations; it is only 14 miles from Pakokku and 13 miles from Yesagyo, while it is situated some 13 miles west of the village of Kandaung on the Chindwin river.

Mandalay District.

The quarries of the Mandalay and Kyaukse districts were examined by R. Ramamirtham at the request of the author, and the following notes are based on his observations:

Yangindaung Hill Quarry.—The Yangindaung Hill quarry is situated about 6 miles from the Mandalay palace; a motor road leads up to the face of the quarry. On the top of the southern extremity of the hillock is situated a pagoda, the approach to which is at the northern end of the hill. The hill

is roughly oval in outline, with the major axis trending in an approximately north-to-south direction. At present quarrying is carried out on the eastern face for a distance of nearly half a mile. The rock that is quarried is a banded, crystalline limestone. In some cases the individual bands approach a breadth of even 2 feet, and may often be suspected to be veins. It is probable that the step-like features which are seen on the slopes of the hill are due in part, if not wholly, to this banding. Above the limestone lies a conglomerate-tuff, and in the portions exposed in the watercourses a whitish-coloured rock is seen which is likely to be calcareous tufa.

The method of exploitation that is adopted is that of open quarrying. At present holes are bored through the rocks with the help of long crowbars and then the whole mass is blasted with dynamite. The overburden here is indeed very heavy : it reaches nearly 50 feet.

The first quarrying operations were commenced nearly twenty years ago. The material is supplied solely to the P.W.D., who in turn use it for road metalling. The steps leading up to the pagoda on top of the hill are made of the stone found in this hillock. The production has not fallen in any way during recent years. There has been a consistent demand for it for the past ten years.

Mandalay Hill Quarry.—This quarry is situated opposite the British cantonment lines of Mandalay town. The quarry face is 150 feet wide, with a height of about 50 feet.

The methods of quarrying adopted here are just the same as at Yangindaung. Work is not carried on continuously, and the reason for this seems to be that there is little demand for the stone.

The rock quarried here is a crystalline limestone containing much mica and pyroxenes. In fact, the whole of Mandalay hill is composed of this crystalline limestone except for a few bands of gneiss which have been highly weathered. R. Ramamirtham says that his attempts to procure fresh specimens of this rock were in vain. Just at the contact of the gneiss and the white crystalline limestone a certain amount of black calcite is developed.

The rock from this hill is being used at the present time as a

soling stone for roads. No attempt to manufacture lime from it seems to have been made.

Quarrying appears to have been proceeding for very many years. The flight of steps that leads to the pagoda on top has been built entirely of this stone.

The overburden here is not very heavy. In spite of this there is no scope for the removal of much material, as the whole hill is being covered with buildings intended for religious purposes, and their construction is still going on. All round the hill there are relics of old quarry sites. The output from these quarries is very small in proportion to the demand.

Tonbo Hill Quarry.—This place is about 7 miles from Mandalay, and can be approached either by motor road or by train. The quarries are quite close to the Tonbo railway station. A railway-siding has been laid to the quarries for a distance of more than half a mile.

This important quarry faces the Mandalay-Maymyo road and is only two furlongs from it. The height to which quarrying has been limited is 100 feet.

The rock composing the hill is a limestone which is somewhat siliceous, and is also traversed by a number of veins which form a network. The overburden here is indeed heavy. The method of exploitation adopted is that of open quarrying. The limestone is traversed by a number of joints, and this renders the removal of stone rather easy. At present along the total distance of 1900 feet quarrying is carried on to a height of nearly 70 feet. The annual output from this place is on an average 2,000,000 cubic feet.

The quarrying here was begun only some fifteen years ago, and from that time onwards there has been a consistent and heavy demand for this stone, both from the government and also from municipalities.

The stone is mostly employed as a road-metal, and only in a few cases has it been used for building purposes. A small portion of this stone is also burnt to make lime.

Kyaukse District.

Within this township and quite close to the town road-metal quarrying is carried out in two places, viz., in the Indaing hill

and in the Patta hill. There is only a cart road leading from Kyaukse town to these quarries, which are situated on opposite sides of the town. Both of these quarries are at a distance of about three and a half to four miles from the railway station.

These quarries seem to have been worked for nearly two decades, and the material from Indaing Hill is largely used for road making, and a small amount is utilised for building purposes ; the stone is capable of being broken into regular blocks of brick size.

Indaing Hill Quarry.—Here the rock that is exposed is a greenish, calcareous slate. The bedding planes are clearly seen, and the rock is quarried without much difficulty. Along the whole base of the hill, and in the upper portions also to a height of nearly 50 feet, quarrying operations are being carried on. The Indaing Hill itself is composed of two or three hillocks and the nature of the stone in each is different. In one it is the greenish and calcareous slate, and in another it is a greyish-white, hard, siliceous rock. The exact relationship between the two types could not be traced in the time at the author's disposal. The same method that is adopted in other places is also employed here for the removal of material.

Patta Hill Quarry.—The rock exposed here is a useful variety of calcareous slate that is capable of being split into thin slabs of different sizes. Here also the rocks dip in the same manner as in the Indaing Hill quarry ; in fact, there is not much difference between the stones of the two places except that, from an economic point of view, the Patta Hill stone can be put to a better use than the Indaing Hill material.

The entire consumption of the stone is in the Kyaukse subdivision, and it is used almost completely for flooring purposes in buildings.

Tharrawaddy Division.

In the headquarters sub-division of the Tharrawaddy division river shingle and gravel from the Tharrawaw shore, Tharrawaddy district, and laterite from Hmawin quarry, Letpadan township, and also from Seinkalan quarry, Minhla township, are used for metalling roads. Large balls of burnt mud (*delone*),

with road-metal and chippings obtained from the Mokpalin quarries, are also used for the same purpose.

In the Zigon sub-division Mokpalin road-metal and laterite obtained locally are used. Some blue sandstone from Ngapaw and Prome also find use for the same purpose. Gravel and pebbles from Hmawza and Tangon are also employed. *Delone* are made in Zigon for the purpose.

Henzada District.

The Public Works Department quarries near Kyweinzu are situated at the foot of the Arakan Yoma hills in thick, dense jungle and within the limits of the Government Reserve Forest, about four miles north-west of Kyweinzu village. Excepting the rough footpath made by the Public Works Department from Tatkon village to the quarry in the north side of Kyainchaung there are no other tracks. These quarries were visited by the late Sethu Rama Rao, and the following notes are based on his observations :

There are two quarries opened by the Public Works Department and both are situated in the stratified rocks of the upper Eocene or Oligocene, and are made up of a series of sandstones, grits, arenaceous limestones and shales. These quarries, being situated in sedimentary rocks, have to be worked in selected areas, where the hard indurated grits and sandstones are exposed. In this area the latter rocks stand out as hills with steep slopes, extending over many miles in a nearly north-north-west–south-south-east direction. The amount of road-metal available for quarrying is unlimited, but is distributed only in narrow outcrops.

Sethu Rama Rao estimated that the supply of road-metal, as exposed in the two quarries, is 80,000 and 78,000 units of 100 cubic feet. He suggested that the continuation of these bands could be worked along the strike, where natural conditions for quarrying are helpful, and thus an unlimited supply could be maintained.

B. BUILDING MATERIALS.

In Burma, excluding its capital and the main seaport of Rangoon, the demand for building stone is very limited, as

most of the houses, especially in small towns and villages, are still made of wood and bamboo. The masonry in towns is mostly constructed of brick and mortar. The building stones largely used in the province are those that are needed by the Public Works Department in the building of bridges, etc.

Federated Shan States.

The Plateau limestones of the Federated Shan States furnish valuable materials for building purposes. A highly fossiliferous band of middle Devonian age, occurring at Padaukpin (22° 6′, 96° 39′ 30″), near Wetwin railway station, would, according to La Touche, yield a very handsome marble, being capable of a high polish.

Some of the harder bands of the sandstones of the Namyau Series (Jurassic), which are well developed in the eastern portion of the Shan Plateau, would yield excellent building stone. The piers of the bridge over the Nam-Tu at Hsipaw are built of this rock and have been found to answer well for the purpose.

Zebyingyi Quarries.—The village of Zebyingyi is situated about 20 miles from Mandalay town, and can be approached either by train or by motor road. The quarries are very near the Zebyingyi railway station. As one alights from the train a number of limekilns and much lime stored up ready for loading can be seen.

At this place there is no quarry worthy of the name. As the limestone quarried here is exposed at the surface, shallow pits not more than 4 feet in depth are dug with the crowbar and the spade. All these pits are situated within a radius of about a mile from the railway station. In certain villages more than 3 miles distant from this place the same stone is quarried and put to the same use. In reality it is the weathered superficial portion that is worked, as this is easy of removal. In the railway cutting just below the railway station one can see good sections of the strata.

Three prominent lime-manufacturers who do business on a large scale are in this place, and there are about thirty other minor merchants. There are also about thirty limekilns, the output from which varies with the season. During the winter

there is little or practically no output, while during the summer season it is at a maximum.

The lime manufactured is used both in Upper as well as in Lower Burma. Of late there has been a gradual decrease in the demand. The cause for this seems to be that numbers of limekilns have been started in the adjacent neighbourhoods of Mandalay, Kyaukse, etc.

Myitkyina District.

On the Mogaung-Kamaing road some of the bridges have been built of blocks of Tertiary sandstones, with limestone and serpentine. Quarries for the last two types have been opened up in Hkakon *hka*, about three-quarters of a mile west of the first bridge in the 22nd mile of the road. Rectangular blocks of Tertiary sandstone were used in the building of the bridge near Namting in the year 1909 ; but the rock, being soft and felspathic, would soon decay in a very humid climate, though it possesses the advantage of being dressed easily. Minor causeways on the Kamaing-Tawmaw road between Namting and Lonkin have also been built of the Tertiary sandstones.

Small outcrops of limestone are quite ubiquitous in the Jade Mines region. At present this rock is little in demand on account of the inaccessible nature of the region. It is, however, burnt for lime in the neighbourhood of Kamaing, for the use of the Public Works Department in the building of bridges, etc.

Shwebo District.

Most of the revetments and abutments of the bridges in the Shwebo district are built of sandstones. They are extensively quarried south of the Shwebo-Kyaukmyaung road, about two and a half miles from Kyaukmyaung.

According to V. P. Sondhi the grey dolomitised limestone of the Mogok Series (forming parts of the Maungdawtaung and the hill near Shagwe), is locally burnt for lime in a very primitive fashion. Several kilns are working, but the total output is small and the quality of the lime is poor.

Near Kyauksegaw laterite is found in the Irrawaddian sands near their junction with the alluvium. The sand is rich in

small, ferruginous concretions, and the laterite appears to have originated by cementation of the residual accumulations of these concretions. The rock does not form a continuous bed of regular thickness but occurs in a haphazard manner, having any thickness up to 12 feet. It is extensively quarried and used for facing canal embankments and in bridge construction.

Lower Chindwin District.

Exposures of compact bedded Pegu sandstone occur along the Ywashe-Yinmabin road, west of Monywa. The stone is suitable for ordinary building purposes and can be easily trimmed and shaped, and is used locally in building bridges and their revetments.

At Maukthayet in the Lower Chindwin district the limestone which occurs interbedded with the Pegu clays is extracted and burnt for lime on an extensive scale, and forms one of the principal occupations of the villagers in this area. Owing to the lenticular nature of the limestone reefs extraction is a laborious process, and many hundredweights of useless rubbly clay have to be excavated to obtain one hundredweight of limestone sufficiently pure for burning. After firing it yields a pure lime which, when slaked, makes a good mortar. After repeated slaking the lime is also used for consumption with the areca nut. In former times Maukthayet lime found a ready market over a wide area in Upper Burma, but the industry has suffered considerably from the competition of the Sagaing lime, and its sale is now restricted to the western parts of the Lower Chindwin district.

Pakokku District.

Two qualities of sandstone for building purposes may be obtained in large quantities from quarries in this district. The first is a yellow, calcareous variety occurring in a bed 200 to 300 feet thick; the stone is somewhat soft when freshly cut, but hardens on exposure to air. The second variety is purple or pink in colour, of medium grain, very slightly calcareous, and harder than the yellow variety. It occurs in layers 4 to 12 in. in thickness, and is even textured, and so uniform in grain. It

is extensively quarried by local inhabitants, and is used chiefly for the construction of pagodas. It is also carved into fantastic images for decoration. In addition, it finds use for making many domestic articles and also for flooring purposes. The prepared stone is widely exported.

Yamethin District.

Limestone is quarried for building purposes from a hill two miles 85° east of north from Taungbotha. It is a medium-grained, greyish (though sometimes interbanded with white), rather coarse-grained, crystalline limestone, containing about 15 per cent. of magnesium.

Thayetmyo District.

Limestone is known to occur commonly along the eastern flanks of the Arakan Yoma, but the most accessible locality is near Thayetmyo, where the Nummulitic limestone, forming a hill to the south of the town, has been quarried extensively for making lime. According to Ranking the lime makes excellent cement, but is not hydraulic.

Bassein District.

Limestone occurs as a band 30 to 40 feet thick near the Bassein river to the south of Thamandewa (16° 23′, 94° 42′), and has been traced for about 2 miles. The quality is good and the locality easily accessible by water.

Arakan.

Limestone is known to occur at several localities along the eastern side of Ramri Island. The most important deposit occurs to the north of Yanthek (19° 8′, 93° 56′), where it occupies an extent of several acres close to a tidal creek.

Similarly large deposits of limestone also occur at Banm (17° 19′, 94° 41′) on the western coast of Arakan. The rock is very pure, containing 96·4 per cent. of calcium carbonate.

Theobald recommended a soft, calcareous, sandy rock occurring on the Kwangyi Island and the adjoining mainland for trial as a building stone. The deposits exist in very favour

able positions for working, as the stone could be loaded into vessels under the lee of the island.

SUMMARY.

Below is given a very brief account of the roadstones and the building materials furnished by the different geological formations developed in the country. It may perhaps be helpful in locating approximately the required kind of stone.

Granite and Gneiss.—The granite and gneiss of the Thaton district has been quarried very extensively in the past and used by the Burma Railways and the Town Lands Reclamation Works in Rangoon, about 300,000 tons having been raised annually. At present the Rangoon, Insein and other adjoining Public Works Divisions are supplied with roadstones from the Mokpalin quarries.

Limestone.—Limestone occurs very commonly throughout Eastern Burma. It has been shown to extend from the Mergui district in the south to the Myitkyina district in the north. Subordinate bands of limestone occur interbedded with the Nummulitic and the Pegu Series. It is the Upper Plateau Limestone, however, that is best suited for the purpose. The Lower Plateau Limestone is too friable, and hence can only be used as a substitute for gravel of small size in the Federated Shan States.

Sandstone.—Sandstone, as shown above, is quarried in many districts, amongst which may be mentioned the Northern Shan States, Meiktila, Thaton, Minbu, Myingyan, Sagaing, Shwebo, Kyaukse, Amherst, Akyab and Sandoway. In the Central Belt and in the Arakan Division the harder members of the Pegu and the Irrawaddian Series are quarried for the purposes in question.

Laterite.—It has already been shown that laterite is extensively developed in Burma and is very widely used as road-metal, and as a building stone for culverts and buildings. For the latter purpose it possesses the advantages over other stones of being easily cut into blocks, and of subsequently hardening when exposed to the air. The output is spread over some twenty districts; but by far the most important are Hantha-

waddy, Thaton, Bassein, Prome, Tavoy and Amherst, all of which lie either on the coast or in the Irrawaddy valley. In the Amherst district the author observed that in the tidal creeks the rock was unsuited for the purpose, as it was easily corroded away by the salt water.

The present supplies of laterite come from Mokpalin, Thaton district, where it rests upon the granite and gneisses. It is reported to be of the best quality and is a hard type. Laterite also occurs in the long narrow ridge between the railways to Prome and Pegu. The quarries for laterite are situated at Wanetchaung on the Prome line.

Trap.—Several kinds of volcanic rock exist and are quarried in the districts of Katha, Shwebo, the Lower Chindwin and the Myingyan districts. The igneous regions of Wuntho, the basalts of the Shwebo and similar rocks of the Lower Chindwin, and the lavas of Shinmadaung and Mount Popa are extensively quarried for road-building and road-mending purposes.

Gravel.—The most important districts where gravel is obtained and used for repairing roads are Henzada, Mandalay, Lower Chindwin, Pakokku, Mergui and Tavoy, the Northern and the Southern Shan States.

Clays.—In Burma clays are extensively used in the manufacture of bridges and pottery, the most important districts being Yamethin, Myingyan, Henzada, Maubin, Pyapon and Hanthawaddy. These come mostly from the alluvium.

C. ORNAMENTAL BUILDING STONES.

Unfortunately few ornamental building stones occur in Burma. But unweathered granite of medium texture and of somewhat varied colour, which occurs so extensively, especially in the Thaton, Amherst, Tavoy and Mergui districts, is capable of taking a good polish and should make a useful ornamental building stone. The author considers that some of the intrusive rocks of the Mogok area could be similarly employed.

The serpentine which occurs so widespread in the Arakan Yoma, the Manipur and Naga Hills, and in the Myitkyina district cannot be used for big ornamental purposes because of its fatal defect of jointing; however, it may be employed

for small ornamental purposes, as it takes a good polish. Similarly, blocks of jadeite, which are considered valueless and simply thrown on the dumps, could be also used for small ornamental purposes, as the rock takes a very good polish indeed. The author has seen beautiful polished tablets of jadeite used for wall ornamentation in Chinese houses in Mogaung.

The beautiful white marble of the Sagyin Hills, 20 miles north of Mandalay, finds much favour with the Burmese, and is used to a certain extent in ornamental screen work. But it is mainly used for carving images of the Buddha, many of which are of colossal size. The stone is brought down to Sagaing, Mandalay, etc., where it is worked into shape.

Marble of a similar kind, often with grey-coloured bands, occurs in unlimited quantities at Kyaukse. Similarly, enormously thick bands of the same crystalline limestone extend across the Ruby Mines area from Thabeitkyin on the Irrawaddy to and beyond Mogok. The texture of the limestone here is much inferior to that of the Sagyin Hill marble. Similarly, farther north, several outcrops of beautiful marble occur in the Kamaing sub-division of the Myitkyina district, especially where the limestone has been intruded by granite or other igneous rocks.[1]

[1] *Rec. Geol. Surv. Ind.*, vol. lxii., 1929, p. 32

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